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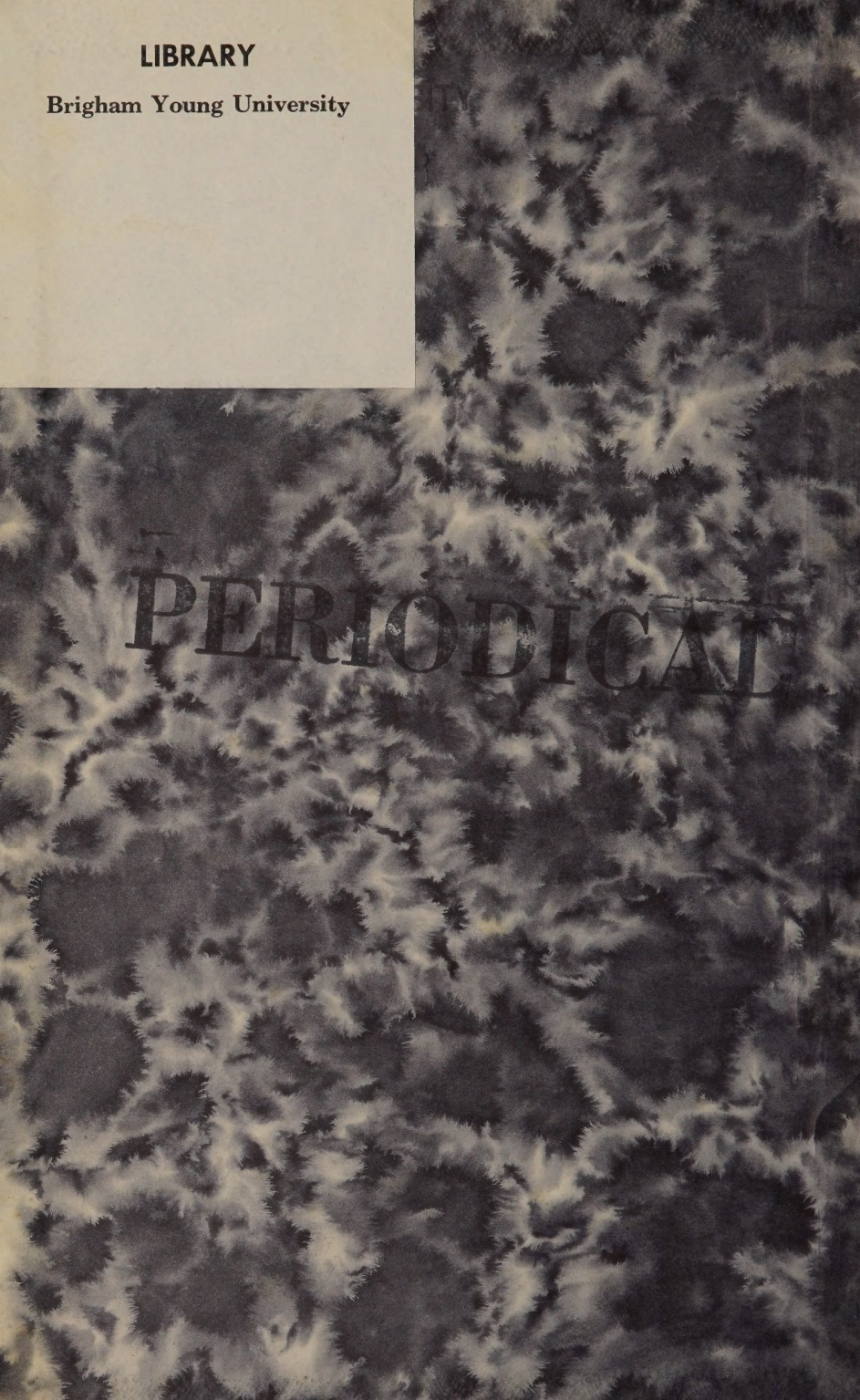

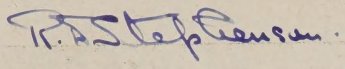

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NSACTIONS

OF

THE CERAMIC SOCIETY

INCLUDING

THE REFRACTORY MATERIALS SECTION.

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RULES

1.—The Society shall be called THE CERAMIC SOCIETY. It shall comprise a special section dealing with Refractory Materials.

2.—The object of the Society shall be the discussion of all subjects relating to the industries connected with Clay Working and Refractory Materials.

3.—Persons desirous of membership shall be proposed and seconded by two members of the General Meeting, and they are then eligible for election at the next Council Meeting.

4.—The Society shall be governed by a President, Vice-Presidents, and Committee a Secretary, and a Treasurer. The officers shall be elected at the last General Meeting of each Session, and hold office until the last General Meeting of the ensuing Session, when they shall be eligible for re-election. Among the Vice-Presidents shall be included all past Presidents who are subscribing members of the Society. A Chairman of Council shall be appointed by the Council. Members of the Council shall be elected to serve 3 years, four members to retire each year, and the retiring members to be eligible for re-election.

5.—The headquarters of the Society shall be the Central School of Science and Technology, Stoke-on-Trent.

6.—The meetings shall be fixed from time to time as arranged by the Sectional Councils. At Stoke-on-Trent the meetings during the Session are usually held at 7 p.m. on the second Saturday of the month.

7.—The annual subscription shall be payable in advance, and shall be fixed from time to time by the Council. Members of the Society who have paid their annual subscription receive a copy of the TRANSACTIONS free.

8.—A firm can join the Society by paying an annual subscription of two guineas. For this subscription the attendance at each meeting shall be limited to three members of the firm, and one copy of the TRANSACTIONS will be supplied free annually.

9.—Notification of meetings shall be sent by post to each member in Great Britain with the name of the subject of the paper for discussion.

10.—In the discussions arising upon any paper, no speaker shall occupy more than ten minutes, or make more than one speech, except by the permission of the Chairman.

11.—Any property of the Society lent to members must be returned within a week.

12.—Any member promising a paper and failing to keep his appointment shall himself provide a substitute.

13.—The Society shall have the prior right of publication of all papers read before it for a period of three months.

14.—Authors must send their papers to the Society before or immediately after the communication has been read. If received in time the paper may be printed in time for the meeting. The official receipt of any paper will be dated from the time it is received by the Secretary.

15.—Members may obtain one copy of each of the back numbers of the TRANSACTIONS at subscription rates, providing they are for their own personal use, and that the number in stock be over 18.

16.—Members who are three years in arrear with their subscriptions shall be informed by means of a printed notice, and if the arrears are not paid within a month their names will be struck off the list *New members are put on the list of members when their subscriptions have been paid.*

17.—A member of the Society may introduce a visitor to an ordinary meeting. A visitors' book is kept to show what non-members are present, and by whom they are introduced. The names of the visitors are read out by the Chairman at the opening of the same meeting.

18.—No alteration or addition to the above Rules shall be made except notice be given in General Meeting, and the alteration or addition passed by the ensuing General Meeting. Ten to form a quorum.

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I.—Science in Relation to the Industries of the Swansea District.[1]

By Cosmo Johns, F.G.S., M.I.Mech.E.

Introduction.

When we speak of the industries of a particular district it is usual to assume definite limits for its boundaries. In the case of Swansea this is not difficult, for by taking Kidwelly on the west, and Port Talbot on the east, with the Basal Grit of the Upper Carboniferous Rocks at its outcrop for the northern boundary, we have included in the region thus defined, a distinct and characteristic industrial area with specific natural resources and commercial facilities with, as its focus, the port of Swansea. In the course of a long industrial history it has witnessed the rise and continual expansion of certain industries; others after a promising beginning have suffered a relative or actual decline. The nature of the natural resources of the district has determined the character of the industries established; a long and varied industrial experience has given the district a a type of manual worker whose skill in complex metallurgical operations has been a great asset. These workers have, when the vicissitudes of trade limited their scope for employment at home, carried their skill to distant regions and thus assisted in the economic development of the world's metallurgical resources.

Resources.

The outstanding feature of the district, thus defined, is the abundance and ready accessibility of its coal supplies; the varied character of the coals, with long flaming bituminous varieties at one end of the series and extremely pure anthracites at the other. With the coal measures exposed and, owing to the structural and topographical features, almost all its seams of economic value accessible at a reasonable depth, it is not surprising that their exploitation began at an early date and has continued to exhibit expansion. With coals of such varied characteristics it is not surprising that some were found

1 Being the Public Lecture delivered in the Technical College, Swansea, Friday, Oct. 18th, 1918.

to be specially suitable for certain metallurgical operations, and their early recognition by the industrial pioneers of the district decided the location and subsequent development of what afterwards became the typical industries. The occurrence of accumulations of blown sands with just that admixture of finely comminuted sea shells which gave, at a high temperature, the necessary bond when used for furnace hearths, aided in the development of the copper industry. The discovery, more than a century ago, that from the very pure silica rock, found in the Basal Grit of the Upper Carboniferous Rocks, a brick of high refractory properties, which did not shrink on heating, could be made, enabled high temperature metallurgical processes to be carried out and has given the name Dinas a world-wide significance. Add to this an abundant rainfall with wide gathering grounds to the north as a source of water supply, and a natural port, already considerable and capable of further expansion, with the great advantage of being the most westerly port of industrial Europe, with ready access to the great maritime trade routes of the world, and the wonder it not that it should be a well-known industrial region, but rather surprise that its great natural advantages should not have led to greater expansion. If disappointment is experienced in a region so richly endowed by nature it must logically follow that the explanation will be found in the shortcomings of the human element that, somehow, failed to take advantage of its great opportunities.

Two Typical Industries.

The smelting of copper was one of the earliest to be established in the district. By the decade 1850-60 it enjoyed a practical monopoly of the copper smelting trade. The copper miners of the world paid tribute to the metallurgical skill of the Swansea copper smelter, and the Welsh process of copper smelting remains to-day, though not now practised, a classical example of a metallurgical art brought to a high degree of efficiency by the genius and persistence of practical men. Unfortunately those who were engaged in those early days in the industry overlooked that law of economic science which states that only those commercial transactions which are beneficial to both seller and buyer are of real and permanent value to the industry concerned. The mineowners of Chile and elsewhere who exported their ores to Swansea considered, and in all probability with good reason, that those who controlled the smelting monopoly dealt unfairly with them. As a logical sequence copper-smelting plants were erected abroad and the copper industry of Swansea received a blow from which it never

recovered. Swansea could never have permanently maintained its premier position as a copper-smelting district, for vast ore supplies have been discovered which it could never have profitably imported, but there were always sufficient supplies available had the industry pursued a normal course of expansion. The natural resources and facilities of the district are undiminished, but a new factor has been introduced which complicates the problem. The metallurgy of copper has made stupendous advances. Lean ores of vast extent are cheaply mined in certain districts. Metallurgical processes dealing with charges of a magnitude much greater than even that of the iron and steel industry have been worked out. Water-jacketed blast furnaces working a total charge of 3,000 tons per 24 hours have been working in America for years. Converters handling 80 tons of matte, and blowing for eight hours, are in successful operation. Electrolytic plants, producing great quantities of anode copper, are at work, and refining furnaces dealing with charges of 220 tons of copper are used with very low fuel consumption. In the utilization of these lean ores the trained metallurgical engineer has had his great opportunity in the application of scientific principles to industrial problems. His striking triumph deserves the careful consideration of those engaged in other metallurgical industries.

The spelter industry, which has for its object the production of metallic zinc, is the second of the local industries, the changing fortunes of which deserve careful consideration. Eminently suited to the district, and conveniently located for the importation of ores, it reached substantial proportions. Long before the outbreak of war it had ceased to expand, a sure sign of decay in an industry for the product of which the world demand was increasing by leaps and bounds. It is an unfortunate circumstance that the metallurgy of zinc is apparently simple, and under favourable circumstances can be carried on in small units. As a matter of fact the metallurgy of that metal is more complex than that of any of the industrial metals used on a large scale. So long as the easily smelted calamine ores were available the Swansea spelter industry could hold its own and ignore the changes through which the industry was passing in other regions. When flotation methods had been perfected and the concentrates of the complex ores of Broken Hill, Australia, were available for smelting, the metallurgical practice of the Swansea district failed to make use of its opportunity. The industry stagnated locally while great developments went on in other countries, and on the outbreak of war, of a total consumption of over 200,000 tons of spelter per annum in this country, nearly three-quarters had to be

imported. The complex ores of our own colonies had to find their market in Belgium and Germany, where the metallurgical skill and commercial ability to utilize them could be found. In the Swansea district such sulphide ores as were used were roasted in such a way that the sulphurous gases were delivered into the atmosphere with the resulting creation of that desert which characterises the district between Llansamlet and Landore. In Belgium sulphuric acid was made from those gases and the spelter industry could earn handsome profits. This pre-war stagnation of the British spelter trade stands on record as a typical case of the result that follows when industry neglects to observe changing conditions and ignores the scientific principles on a knowledge of which depends the success of the industry. To-day the conditions are different; under outside pressure smelting extensions have been erected; acid recovery plants are in course of erection, and the industry is passing through a stage of rejuvenation. But even with all the extensions built, or projected, the total smelting capacity will only amount to about one-half of the pre-war national consumption. This does not meet the demand of the Empire for smelting facilities for the ores it does and can produce. The American zinc smelting centres are so situated that they cannot deal with them, and are sufficiently occupied in exploiting their own ore reserves Australia, owing to climatic and other conditions, cannot smelt her great output of complex ores. There only remain Great Britain, Belgium and Germany to be considered. The moral is obvious. Unless the spelter industry can be still further expanded in this country the control of the concentrates that our Dominions beyond the seas can produce will revert once more to the interests that formerly dominated the industry. The complexity of the metallurgy of zinc has been referred to. A great amount of research has been in progress during recent years; electric furnaces for the distillation of zinc have reached the stage where at any moment a commercial process might be announced. The electrolytic method of obtaining pure zinc has long passed the experimental stage and large plants are in operation. One now approaching completion in America will have an output closely approaching the whole of that of Great Britain before the war. The future of the spelter industry will rest in the hands of those who can efficiently apply the principles of science to its changing conditions. Only large plants will be able to afford the skilled supervision necessary to carry out, and profitably apply, the research work required and be powerful enough to deal with the commercial problems involved. A recognition that the old era has come to an end and a new one commenced is the first

requirement for a successful future for the spelter industry of the district. A grouping of the smaller units would perhaps be the best guarantee of their future stability.

These two examples of typical industries which, despite the favourable circumstances of their location, have suffered such vicissitudes have been cited because they serve to illustrate the danger which attends any industry which fails to look ahead and to prepare itself to solve those problems which the progress of science and changing economic conditions are always presenting. The infraction or neglect of the laws of science, economic as well as physical, carries with it a dire penalty that none may escape.

Fuel.

For an expanding metallurgical industry it is necessary that suitable fuel should be available, and as the output of iron and steel must always greatly exceed that of all other metals combined, coal for coking and for gas producers are specially necessary. It so happens that there is apparently a lack of these particular types of coal in the western portion of the coalfield, yet it is already known that the coal seams exhibit a gradual transition from the purest anthracite to highly bituminous qualities when traced laterally and vertically through the coal measures. If the production of pig-iron and steel is to be increased to the extent foreshadowed as necessary for the economic stability of the country it would seem highly desirable that immediate steps be taken to investigate the coals of the district on scientific lines, and to determine which, if any, of the seams can alone or as part of a mixture be rendered available for metallurgical purposes. It cannot be expected that isolated attempts to provide a solution of the problem by individual works will be promising. It rather calls for concerted action by coalowners and the iron and steel works of the district. Experiments with different types of modern gas producers would cost but little if the outlay was spread over the industry, and could not fail to be remunerative if carried out under scientific supervision. Any such research work should keep in touch with the investigations now being instituted in South London under the direction of Sir George Beilby on behalf of the Government.

The Anthracite Problem.

That the vast anthracite deposits of the western part of the coalfield have not been favoured with the same appreciation as the well-known Welsh steam coals is a constant subject of remark and complaint in the district, but it does not appear

that any concerted effort has ever been made to demonstrate its value. The ordinary house and steam coals of this country are firmly established as the acceptable fuels. Competing selling or shipping agents, whose chief incentive to a hesitating purchaser is to remind him that a strike of the anthracite miners is imminent, and that he should thus purchase without delay, are somewhat indifferent propagandists of the virtues of anthracite. The anthracite producers should combine for the purpose of finding new markets for their output, establish a research and publicity organization for the industry, and co-operate intelligently with any movement that promises a new outlet for their product. It has recently been stated by a well-known engineer, with large experience, that marine propulsion by means of gas engines is practicable on a commercial scale; this is a proposal that should receive eager recognition in the Swansea district. Apparently this suggestion passed unnoticed though the technical press gave it abundant publicity.

Refractories.

The district is specially favoured in an abundant supply of high quality silica rock for the manufacture of silica bricks, but apparently there is a dearth of high class fireclays, and no dolomite is being quarried in the district. Now if it be ultimately proved that in the vast extent of coal measures visible in the district there does not occur one single bed of fireclay of a quality equal to that found in the eastern portion of the coalfield the western portion of the South Wales Coalfield will be unique. It is more likely, seeing that the fireclays of the Swansea district have never been investigated on scientific lines, that such clays do exist and have probably been passed through many times during the sinking of shafts or driving of adits, but were unrecognised. The development of the spelter industry has been seriously retarded owing to the difficulties experienced in obtaining the necessary refractory materials, and in this industry alone the money lost would have paid for a complete survey of the district. That such a survey should be undertaken without delay is one of the most pressing needs of the district. Whether it should be conducted by the Government or by an association of the industries concerned is a matter for the careful consideration of those interested. The silica brick manufacturers of the district have by the fortune of war a great opportunity of re-establishing their export trade. The Welsh Dinas brick is still favourably mentioned abroad, and a policy that would recognise the paramount importance of maintaining a consistent high quality for all

exported goods would meet with its due reward. One unscrupulous maker or agent could, by sending goods abroad that were too inferior for use at home, bring disrepute on the Welsh Dinas brick. It is for the whole of the makers interested in export, by concerted action, to devise means to prevent this.

Iron and Steel Manufacture.

As a result of changes foreshadowed before the war and hastened by the restrictions imposed by it, we find the district called upon to change its methods, and from being a typical area for the production of acid open-hearth steel to become chiefly a producer of basic steel. This change, probably a permanent one, brings new problems for solution. The comparatively rich hæmatites being no longer available recourse must be had to either the low grade Jurassic ores which crop out along a broad belt from Oxfordshire to the north of Yorkshire, or to ores from overseas. It is unfortunate that the Swansea district should be so far from the English ore deposit; in that respect they suffer with the Clyde district. It is more likely that, when commerce resumes its normal trend, the Swansea district will look to the great French deposits near Caen for an almost inexhaustible supply of iron ore. These deposits are richer in iron than the Jurassic ores of England, but they are rather higher in silica and lower in phosphorus. They were good enough for Germany to import into Westphalia, so they can be but economically available for the sea-board ironworks of South Wales. France, even without the portion of the Lorraine ironfield wrested from her half-a-century ago by Germany had to import fuel for her iron industry. Now with the largest ore reserves of any European country she must be an exporter, and the Swansea district is the most favourably situated metallurgical district for smelting them. The basic open-hearth steel industry requires dolomite and pure limestone for its development. Limestone occurs in abundance, much of it of a high degree of purity, yet cases are known of works, through failing to recognise the importance of low silica in the material used, being content to use impure limestone with the consequent increase in manufacturing costs. Dolomite is an essential refractory material for the operation of the basic process; it has yet to be proved that there are no suitable dolomite deposits available in the district. The commissioning of a trained geologist to investigate the rocks of the Swansea area would not be a serious undertaking for the industry when once it has learnt that science may solve many a problem that appears insoluble to the ill-instructed.

Tin Plate Manufacture.

The manufacture of tin plates is so firmly rooted in the district; it has withstood so many rebuffs of fortune and has continued to expand on such a scale that here would appear to be an industry so completely stabilised in its technical processes that research would be not only unnecessary but inapplicable, for methods have become so standardized and workers so expert that increased efficiency would be difficult to achieve. It is just that industry, stabilised and standardized, which offers the most promising field for research and development. The cotton industry in this country had probably reached a state of technical efficiency equal to any or even superior to any other in this country before the war, but the leaders of the industry have thought it desirable to form an association for research on broad lines. The formation of an analogous association by the tin plate industry would be evidence of wisdom and prudence. The difficulty is not so much to suggest subjects for research as to decide between the most pressing. Electrolytic pickling has achieved great economy in acid and metal in some industries at a small cost for electric power. At least two systems of surface combustion are now available for low temperature heating furnaces, and one has long passed the experimental stage. By this means steel sheets could be heated to a rolling temperature with little oxidation and a reduced percentage of wasters. An investigation on a commercial scale would not be beyond the capacity of the trade. New uses for tin plate depend to a large extent on the resistance of the tinned surface to vegetable and other juices or solutions. Research on an extensive scale has been in progress in America for some time with a view to determining the conditions that favour the most protective coating with the lowest weight of tin per unit area covered. Here are three lines on which research could profitably be directed with the certainty that once started fresh problems would present themselves faster than the old ones were disposed of. The electrolytic deposition of thin iron sheets is technically possible, and costs have been mentioned that suggest its commercial possibility. The day is probably distant when melting furnaces and hot mills are replaced by electrolytic tanks, but the possibility would not be overlooked by an industry that occasionally projects its vision into the future.

District Power Supply.

It will have been noticed that in each industry discussed the trend is in the direction of the use of electric power.

The electrical transmission of power is the only method that meets the need of modern industries; it is the only practicable means by which surplus energy at points where it is available can be collected and distributed to places where it can be used. Electric power is increasingly used in metallurgical operations and in the case of the non-ferrous metals electrolytic processes are firmly established. It is not too much to say that the progress of any metallurgical district to-day will be conditioned by the rate at which electric power can be obtained. It has already been proved that cheap electric power is not confined to regions endowed with large waterfalls. The very effective organization that controls the supply over the N.E. of England is supplying power in bulk at a price per unit equal to that charged at Niagara. What has been done there is possible in the Swansea district, but it cannot be accomplished by local authorities exercising their power over limited areas. The whole district, as defined, must be organised and controlled and every interest represented. It would be difficult to set limits to the possible industrial expansion of a district, so richly endowed by Nature as the one now under discussion, if advantage were but taken of the opportunities that the progress of electrical science now renders available.

The Spirit of Scientific Research.

The leading industries have now been discussed and an effort has been made to show the scope that exists for properly directed scientific research that could hardly fail to be remunerative. A striking example of the value of research when it is carried out by men of the requisite scientific attainments exists in the district. An investigation which took the form of observing the influence of hot gases on certain alloys, and was an effort to solve a pressing industrial problem, gave disappointing results as far as the immediate object of research was concerned, but a new fact had been noted. It was only recognised to be new because those directing the research had been trained in pure science and thus were accustomed to inform themselves, as a necessary qualification for undertaking research work, as to the state of knowledge in that particular subject. The new fact led to further research in a direction that differed from that originally contemplated, nickel carbonyl was discovered and the great works at Clydach stands to-day as a monument to the value of scientific knowledge when applied to industrial problems. Often has it been the case that the solution of the original problem has evaded the investigator while some

unexpected discovery has been made bringing fame, and no inconsiderable profit, to those who were skilled in the application of scientific principles. But all this demands that those responsible for and directing the research should possess something of its spirit. It must be founded on a sound knowledge of pure science. The idea that it is only necessary to take a work's analyst, call him a chemist, and ask him to solve complex industrial problems is still firmly rooted in this country. The product of a technical school is still called a scientist, even though his knowledge of scientific principles is rudimentary and his training in technology very limited. It is too often overlooked that those who are called upon to apply the principles of science to the problems of industry should at least possess a sound knowledge of those principles. In the domain of industrial research it is a truism that knowledge of the technology of the industry is of secondary importance to a sound training in pure science and proved ability to undertake research work. A tin-plate work's manager, or even a committee of them, would almost certainly fail to elucidate the conditions that would favour the deposition of a coating of tin on steel plate that would give the maximum of protection with the minimum expenditure of the more valuable metal. It would, however, be a most appropriate problem for a physical chemist of proved ability in research, even if he had never seen a tin-plate works, to undertake. The most promising results in the investigation of refractory materials will be obtained when the work is entrusted to highly trained scientific men who are fortunate enough to have escaped close contact with the worries of the manufacture and thus can bring a mind free from bias to the consideration of the problems that demand solution. The solution of the problem of removing dust and mist from the gases produced in chemical and metallurgical processes had baffled the leading chemical and metallurgical engineers as well as their works' chemists until a professor of pure science applied the principles that govern high tension electric currents, took into account the recent advances in knowledge of the constitution of matter, and invented a method of precipitating dust and mist which is now being largely adopted. It might be mentioned for the benefit of those who have not yet grasped the meaning of the true spirit of science that Professor Cotteril devoted the profits of his invention to the encouragement and endowment of scientific research in his country. It was a lady, Dr. Marie Stopes, who recently published, as a result of her paleo-botanical investigations, a statement of facts and conclusions relating to constitution of coal that must have a great influence on the research work

now in progress in many centres with a view to elucidate the most suitable conditions for the scientific use of coal in industry.

Science and Technology.

But all this discussion of industrial research and its methods only serves to bring into prominence the fact that the district is, for one so important and so clearly defined, almost unique in lacking an institution for the higher teaching of science and technology. The ill-fated policy of the educational authorities of Great Britain in thinking, a couple of decades ago, that they had effectively wedded science and industry by establishing technical schools in all considerable towns in the country has had as a consequence the retardation of the spread of real scientific knowledge. These schools did useful work: they taught the technology of several industries and gave some students a knowledge of scientific principles when they could evade the pressure of local opinion which demanded "applied" science, which does not happen to be science at all. The spirit of the manufacturer who brought his son to a well-known professor of chemistry and demanded that he should be taught soap manufacture and not science still lives in the land. The basis of all real progress in the technology of industrial processes must be a sound knowledge of the sciences whose principles are being applied. It has been stated recently, without contradiction, that there were, before the outbreak of war, barely sufficient students in the whole of this country with the necessary qualifications to fill one of the larger German Universities devoted to higher teaching in science and technology. The problem is not one of meeting needs of a particular district; it is not even that of affording sufficient facilities for higher training in this country. The empire looks, and will continue to look, to this country for its supply of highly trained scientific workers and engineers. Mining, chemical, metallurgical, electrical and mechanical engineers will be required for the re-shaping of the industrial world. Imperfectly developed countries like those of South America and the vast regions of Asia and Africa with only partly explored mineral wealth must continue to look to the more highly organised industrial countries for leaders. These can only come from the United States, Germany and Great Britain. The last mentioned lacks facilities for training even the men that its home industries require. Therefore no university college or improved technical college will serve the purpose intended. A project for establishing a school of mines or institution for higher teaching has been contemplated or discussed in Swansea for at least thirty years, so if the present earnest effort to realise the dream of a few enthusiasts should

at last prove successful the local authorities will certainly escape the charge of being called precipitate or hasty in their action. But the local ambition that the new institution might qualify for admission as a constituent college of the University of Wales suggests that good intentions might serve to obscure the real nature of the problem that is demanding solution. We built technical schools in the days when university colleges were required. It will hardly further progress now to erect university colleges when something of more importance is required. What industry, the country and the empire require, are institutions of the highest type that can hold their own with those of Germany and the United States. Several universities in the provinces are making progress towards meeting that demand, but the type required is that of the Imperial College of Science and Technology in London, and the Swansea district, if it really means to make an effective contribution to the requirements of the country, will insist that the standard of any degrees or diplomas given by the institution it proposes to bring into being and the general level of its teaching shall at least be as high as that of the Royal School of Mines, which is a constituent college of the Imperial College. It cannot hope to rival its buildings and equipment; it will start far short of the wealth and without the prestige of the old school that has sent its students to the far corners of the earth, but it can commence with the same high standard, capture something of its spirit, and in time build up a friendly rival which will have one great advantage of being located in the focus of the most interesting and varied metallurgical district in Europe.

The degrees of a new university with ill-defined aims are but a poor substitute for the diploma of an institution that has succeeded by the high level of its teaching, the sound ideals of its founders, and the worthiness of the succeeding occupants of the professional chairs in sending out trained men whose attainments and standard of professional conduct have contributed to its prestige and assisted in the development of the mineral wealth of the empire. If the district of Swansea is willing to accept the standard suggested; if the same ideal that prompted those far-seeing men who made the small beginnings in Jermyn Street that eventually led to the creation of the Imperial College in South Kensington is adopted the way is clear, for faith in an ideal can remove mountains of difficulties. Professors of mathematics, physics, chemistry and geology should be elected before buildings are erected or technology thought of. They should be men old enough to have made their mark and proved their capacity for original

work in the sciences they profess; while still young enough to retain the energy to build up out of nothing the institution required. It is fortunate that pure science demands no vast equipment; it is only technology that considers that it ought to surround itself with miniature works. And it is not without significance that even with technology it is not institutions with the most elaborate equipment that have made the most original contributions to knowledge. When, and only when, pure science has been amply provided for, need thought be taken for the teaching of technology.

The Work of the Proposed Institution.

Whatever may be the name eventually adopted for the proposed institution there need be no difficulty in defining its functions or the standard to be aimed at. It is to provide for the training and inspiration of the men, and if needs be the women, who seek to occupy positions of responsibility in the metallurgical and related industries, not merely of the district immediately served but of the British Empire. Success will have been achieved when those who have been trained within its walls have given proof, when faced with industrial problems and commercial responsibility, that they possess not only the necessary knowledge of science and technology but enjoy a reputation for a standard of professional conduct at least equal to that of the old students of the Royal School of Mines, London. It is very probable, unfortunately, that financial considerations will severely limit the scope of the new institution for some considerable time. To perform its functions fully it ought to provide for the training of mining engineers (metalliferous), metallurgical engineers, mechanical engineers, electrical engineers and chemical engineers. The first three at least ought to be provided for at an early stage. But while the engineer must be the type principally provided for the provision of facilities for training research workers cannot be overlooked. The engineer, whether mining, metallurgical, mechanical or other type, needs initiative and the ability to command and direct manual labour. Courage in facing difficulties, intuition in evading them, and the stamina required for prolonged exertions are all requisite. All men do not possess these qualities; some will be found who, during their training, will display special aptitude for research and give promise of a capacity to further extend the boundaries of knowledge. These are the men, though women too have possessed these gifts, whose training should be specially directed to extending further their grasp of the principles of science, to developing their powers for research work and

thus to produce a type of scientific worker to whom the nation and the empire can look for the solution of those problems that industrial progress and international rivalry will present in ever increasing numbers and growing complexity. This would not be the standard of a mere university college; it would be a misfortune for any such institution to suffer the restraint of a supervising university of no well founded status itself. It should at least be autonomous, loosely associated possibly with the university at first if no escape be open but determined, sooner rather than later, to stand by itself when its ideals had been realized, and to co-operate by exchange of students with other institutions within the empire of equal standing. As its growth and development would be a national gain, and the realization of its ideals would constitute a bond with the dominions beyond the seas, its upkeep should not be the sole or even a considerable charge on the local community. Welsh members of Parliament would have a good case to call on the Government of the day to state why they should not contribute on a scale that would approach, if only approximately, the money that Germany thought necessary to pay yearly to so many of her numerous centres of learning.

Economic Science and Industry.

Physical science, and its applications, cannot meet all the requirements of that section of mankind engaged in industrial pursuits. The establishment of good relations between the representatives of capital and labour; the enunciation of well defined principles which would make clear the community of interests of related industries have not passed the stage of empirical rules, and even these are not generally recognised. So far as they have advanced it has been at the cost of painful trials and grievous errors. Economic science has a message to deliver, if its laws are obscure it is because industry has failed to recognise that its activities are governed by any scientific law, and opportunities have been rare for the study of such special problems as are constantly arising in any great industrial area. He, indeed, would be a far-seeing and most wise citizen who would endow a chair of economic science, on a scale sufficiently generous to attract a man of wide attainments, whose occupant could find in the study of the economic changes of a well defined industrial area scope for careful observations, and the opportunity for such earnest teaching that a whole community might be so educated that all, whether capital or labour, and even those whose task it is to apply scientific principles to industry, should be so occupied in performing their duties to each other that there would be no occasion to quarrel about their rights.

II.—The Setting of Plaster.

By Prof. C. H. Desch.

REGARDED as a chemical process, the setting of plaster is exceedingly simple, and was correctly explained in its main features as far back as 1765, when Lavoisier[1] gave the following account of it:—

"If, after having removed the water of hydration from gypsum by fire, it be returned to it (which is commonly called gauging the plaster) it takes up the water with avidity, a sudden and irregular crystallization takes place, and the small crystals which are formed becoming confused with one another a very hard mass results." Lavoisier also remarked certain other facts, the most important of which were that the loss of water on heating gypsum did not take place at one time, but that three-fourths were driven off at a much lower temperature than the remaining fourth, and that heating to too high a temperature led to the formation of a product which would not set. These statements embody the greater part of our knowledge of the setting of plaster, although further work has expanded them, and many details have been added.

An anhydrous salt does not invariably set when taking up water to re-form the hydrate, so that some further explanation of the setting is required. This was furnished, in the case of plaster, by Le Chatelier in 1887[2], who showed that gypsum, which is the dihydrate of calcium sulphate, $CaSO_4.2H_2O$, passes at about 128° C. into the hemihydrate, $2CaSO_4.H_2O$, and that this substance constitutes the bulk of ordinary plaster. The solubility of the hemihydrate is considerably greater than that of the dihydrate, as had been shown in 1873 by Marignac,[3] who shook plaster with a quantity of water and filtered rapidly. The clear solution thus obtained had several times the concentration of a saturated solution of gypsum, but was unstable, and soon became turbid owing to separation of small crystals of gypsum. On this fact, and on microscopical observations of the reaction with water, Le Chatelier based his account of the setting process. On mixing the burnt plaster with water each particle soon becomes surrounded by a layer of a solution which is saturated with regard to the hemihydrate, but strongly supersaturated with regard to the stable gypsum. Crystallization of gypsum soon begins, either spontaneously or more probably from nuclei which have persisted unchanged

throughout the burning process. Growth of the crystals taking place from many neighbouring centres, radiating groups are formed, and the interlocking of these is at least one of the causes of the strength of the mass. It has been observed[4] that salts which crystallize from strongly supersaturated solutions, and can exist in several different states of hydration, have a strong tendency to group themselves in spherulitic forms, and the boundaries of neighbouring spherulites are naturally apt to be irregular. In the case of plaster gauged with the customary amount of water the crystallization is so minute and confused as to defy microscopical study, but the process may be so far retarded by the addition of alcohol that it may be followed under the microscope, the crystals thus formed being of appreciable size.

Other salts behave like gypsum in this respect, provided that there is a sufficient difference of solubility between the anhydrous and the hydrated form. Anhydrous sodium sulphate has a solubility greatly in excess of that of the hydrate,[5] and if precautions be taken to avoid a rise of temperature a strongly supersaturated solution may be prepared, from which the stable hydrate subsequently separates. If the quantity of water used be comparatively small the salt sets like plaster, and the same is true of many other salts, including barium metasilicate, which has many of the properties of a cement. Recent work by Lowry and Hemmings[6] has shown that the caking of certain commercial salts, which often causes trouble in packing, is due to the same cause. It is to be noted that the quantity of water which brings about the setting or caking may be very minute in proportion to that which would be required to dissolve the whole of the salt, even in the form of the unstable anhydrous modification. Taking Marignac's figures it appears that, if 60 c.c. of water be used to 100 g. of plaster, that quantity will only be sufficient to dissolve $^1/_{166}$ of the hemihydrate, or $^1/_{1000}$ of the hydrated gypsum. It follows that the process must be one of successive solution of minute quantities of hemihydrate followed by deposition of dihydrate, the balance of the water set free again dissolving more hemihydrate, and so on.

Accepting this outline of the setting process as being on the whole correct there remain many points on which further knowledge is desirable. What is the reason for the quite considerable mechanical strength of the plaster after setting? According to Le Chatelier this is due to the lath-shaped crystals radiating from neighbouring centres interlocking with one another, as the fingers of one hand, held out stiffly, may be made to interlock with those of the other hand. There is, however, another aspect to be considered. All recent work on metals goes to show that boundaries between neighbouring

crystal grains in a mass of a pure metal or homogeneous alloy are surfaces, not of weakness, but of strength. This may be attributed, in accordance with the theoretical ideas of Beilby, to the existence of surface tension in the boundaries, or it may be regarded, as Rosenhain has proposed, as due to the presence of a layer of amorphous material, chemically identical with the crystals, between the surfaces of the latter. In either case the interlocking boundaries would be a source of additional strength In comparing plaster with metals, however, it must not be forgotten that plaster after setting is porous, so that the contact between the spherulites is not so complete as in a mass of cast metal. It is probably only along a part of their length that the lath-shaped crystals are actually in contact with one another.

A second point of interest relates to the change of volume during setting. The reconversion of the hemihydrate into gypsum is accompanied by a decrease of volume, that is, the dihydrate occupies a smaller volume than the sum of the volumes occupied by the hemihydrate and the water with which it combines.* At the same time the fact that an expansion is actually observed is well known, and is the reason for the use of plaster for taking casts, the mass expanding at the moment of setting, and so filling the fine recesses of the mould. This apparently contradictory behaviour has been explained by Davis[8] as due to dimorphism. According to his observations the first product of hydration is not gypsum, but an orthorhombic modification of the dihydrate, and the contraction which accompanies its formation is followed by an expansion due to a change into the stable, monosymmetric gypsum. This may be responsible for a part of the volume change, and it is partly confirmed by dilatometric measurements, which show[9] that a large contraction takes place during the first half-hour, followed by a subsequent but smaller expansion, which continues over several hours. I cannot regard this, however, as a sufficient explanation of the familiar behaviour of plaster in a mould The expansion is sudden, and obviously accompanies the setting instead of being a slow secondary effect. Coupled with the known porosity of the mass after setting, I prefer to consider the expansion as only apparent and caused by the outward thrust of the lath-shaped crystals during their growth. That growing crystals can actually exert a thrust in the direction of their growth is proved by a large body of

* Density of the hemihydrate 2·75, and of gypsum 2·32. $2CaSO_4\,H_2O=290$; $H_2O=18$; $CaSO_4$, $2H_2O=172$. Volume before setting $=\frac{290}{2\cdot75}+\frac{3\times18}{1}=159\cdot5$. Volume after setting $\frac{2\times172}{2\cdot32}=148\cdot1$; a contraction of 7 per cent.[7]

evidence,[10] and has been directly demonstrated by recent experiments.[11] [12] The crystals of gypsum thrust each other apart, and the resulting mass is porous, with a greater external volume than corresponds with the true volume of the component crystals.

The chemistry of the burning of plaster is rather complicated. The products of the dehydration of gypsum include, in addition to the hemihydrate, at least two modifications of the anhydrous salt, of which one, known as soluble anhydrite, has setting properties, whilst the other, probably identical with the naturally occurring mineral anhydrite, is almost inert towards water in experiments of short duration. The relations between these modifications have formed the subject of many investigations. The conclusion reached by van't Hoff and his co-workers[13] was that soluble anhydrite was the stable product of dehydration, and that the hemihydrate was only a metastable phase, and the transformation was studied in detail by Armstrong,[14] who found that the hemihydrate might be prepared in a pure state in the laboratory by the action of warm concentrated nitric acid on gypsum. This method furnishes a convenient material for the study of the behaviour of the pure hemihydrate. There is no doubt that soluble anhydrite is often present in freshly burned commercial plasters, although it absorbs moisture so readily from the air that conversion to the hemihydrate is almost complete when the plaster has been made for some time. I am not aware of any systematic study of the conditions of setting of soluble anhydrite in comparison with the hemihydrate, but it appears that a small expansion takes place, probably from the same cause as that described above.

When the burning of gypsum is carried out at too high a temperature the product no longer sets with water, but either remains inert or slowly hydrates without hardening or expansion. Such plaster is said to be "dead-burnt." Much controversy has occurred as to the temperature at which plaster becomes dead-burnt. Rohland[15] and Hursh[16] agree that above 200° a form of anhydrite is obtained which hydrates slowly without setting, but differences of opinion appear as to the higher temperatures. According to Rohland, the non-setting form is of high molecular weight, and at about 525° dissociation into simpler molecules takes place, with the formation of a second anhydrite which sets very hard without expansion. This is the material largely used in Germany, and to some extent in other countries, although almost unknown here, under the name of Estrichgyps or flooring plaster. It hardens very slowly and cannot be used for moulding purposes, but the resulting product is so hard as to resemble a cement rather than a plaster,

and is capable of withstanding the hard wear of a floor. Rohland further states that above 600° a third form of anhydrite is produced, which is incapable of setting or hardening, and is thus completely dead-burnt. Rohland's figures for the supposed transition temperatures are worthless, as he produces no evidence of any state of equilibrium, and they are completely contradicted by technical practice. Estrichgyps is usually burnt at 900° or more, and according to Glasenapp,[17] whose work on this point is valuable, it is not formed below 800°. Glasenapp observed that the burnt product retained something of the original crystalline form of the gypsum up to 800°, but that above that temperature it became granular, such a granular structure being characteristic of flooring plaster. Moreover, at a red heat a certain amount of decomposition of the calcium sulphate takes place, with the formation of a basic sulphate, which may play some part in the hardening. Glasenapp found that a product containing as much as 83 per cent. of calcium oxide still sets quite hard, without appreciable change of volume. He considered that the basic sulphate formed a vitreous coating to the granules of anhydrite.

Recent work goes to show that the differences between the supposed modifications of anhydrite are largely due to mere differences in the fineness of the particles, and I am by no means convinced that there is any real evidence for the existence of more than a single modification of anhydrite. Winterbottom, in a very useful monograph,[18] shows that very great differences in the rate of setting and the strength of the hardened product may be brought about by fine grinding, and similar experiments have been made by Keane.[19] This author suggested that even natural anhydrite would set if sufficiently finely ground. Geological evidence favours the view that gypsum is sometimes formed in nature by the hydration of anhydrite, and it might be expected that, given sufficient time and a sufficiently intimate contact, the hydration would take place. This has been confirmed in a recent publication by Gill.[20] Specimens of finely ground natural anhydrite and of dead-burnt plaster in rough lumps were covered with water in closed bottles some seven years ago. On opening last December both substances were found to have been very largely converted into gypsum, which had formed large crystals with expansion, the thrust in the case of the dead-burnt plaster having broken the glass. It is therefore clear that both substances can set.

That differences of setting properties may be to a great extent due to differences of density and physical condition is proved by the experience of workers with other substances capable of hydration. Lime which has been melted in an electric furnace solidifies to a crystalline mass, which is only very

slowly acted on at the surface by water, but if finely powdered and mixed with water it remains apparently inert for a short time, and then reacts with almost explosive violence.[21] So also, magnesia which has been ignited at a high temperature (up to 1,450°) requires a period of time for hydration which is measured in years.[22] Such facts may account for the supposed inertness of anhydrite. How far the fineness of grinding may affect the conclusions may be seen from an experiment of Keane.[19] Gypsum which had been heated for some time at 600° was ground so that the average diameter of the particles was 0·05 mm., and then behaved as a dead-burnt plaster, being unable to set. The same product, ground until the average diameter was reduced to 0·005 mm., set rather rapidly, forming a hard mass. Besides increasing the surface area, fine grinding brings about the formation of a quantity of amorphous material, the solubility of which is greater than that of the crystals.

Time as well as temperature is concerned in the burning process, prolonged heating at a lower temperature producing the same effect as a shorter heating at a higher temperature. Much of the observed effect may, I think, be attributed to the occurrence of sintering during burning. As already mentioned, heating at 1,000° leads to the formation of some basic sulphate, which glazes the particles and gives them a closer texture. It is quite probable that at lower temperatures small quantities of impurities may produce a similar result, and it would be interesting to compare the behaviour of pure calcium sulphate and that of more or less impure commercial plasters in this respect. Undoubtedly the size of the particles of gypsum before burning influences the properties of the burnt product.

Looked at from the point of view of the ceramic industry the principal requirement of a good plaster for moulds is porosity, always supposing the strength of the hardened plaster to be sufficient to resist the pressure of the moulding or casting process and the removal of the ware. Accepting the explanation given above, that the porosity is produced by the outward thrust of the gypsum crystals during growth, it would be favoured by rapid crystallization from a supersaturated solution. In order that the hemihydrate shall pass rapidly into solution it must be in a fine state of division, and this is best brought about by grinding the gypsum finely before burning, and avoiding any sintering during burning. Should slight sintering take place, owing to the presence of small quantities of impurities, this may be corrected by regrinding the burnt product to a fine powder. It is necessary for quick setting that a little of the crystalline dihydrate (gypsum) should be present in the finished plaster, in order to provide the nuclei for the crystallization of the supersaturated solution, and the rapidity of

setting depends, among other things, on the proportion of gypsum present. Gypsum accelerates the setting, whilst insoluble anhydrite retards it. Ordinary plaster contains some water which may be removed by heating at so low a temperature as 50° for several hours, and this is often returned as "uncombined" water,[23] but it may very probably represent gypsum in a very fine state of division, as gypsum has been dehydrated by heating in dry air at 70°.[24]

A brief reference may be made to two other views as to the nature of the setting process. Rohland[25] has suggested that water is taken up by the plaster to form a colloid, but has not produced any evidence in favour of this view, whilst Cavazzi,[26] noticing that a gelatinous mass is formed when fresh plaster is ground with water in a mortar, crystals appearing subsequently, has assumed the formation of a highly hydrated intermediate product, which then loses water. It should be noted, however, that Cavazzi employed a much larger proportion of water than is used in gauging plaster.

A brief mention must be made of the influence of catalysts on the setting of plaster. Many salts accelerate the setting, especially the soluble sulphates, whilst others, including borax, retard it. Generally speaking, the accelerators are substances which increase the solubility of gypsum (or, more probably, of the hemihydrate), whilst retarders are substances which diminish the solubility.[27] Colloids usually delay the setting. These facts are made use of in the preparation of technical plasters, and I cannot now discuss them in detail, but will only remark that such additions influence, not only the setting time, but also the strength of the plaster, as in such well-known products as Keene's cement. I am not aware of any studies of the corresponding influence on porosity, but many facts bearing on this point must be known to persons engaged in the plaster industry, and it would be interesting to have them placed on record. The whole subject of the setting of plaster is well worthy of further investigation.

A few words may be added in reference to a question which I understand is of special interest to the ceramic industry, namely, the recovery of plaster from used moulds. Assuming that the failure to make good plaster by re-burning old moulds is due to the absorption of soluble salts during use, thus completely altering the setting properties, it should be possible to wash out the salts from the coarsely broken material before submitting to re-burning. Such a washing process is applied in the manufacture of plaster from such gypsum deposits as those found in some parts of South Australia, containing a large proportion of soluble salts. It would be necessary to

grind the burnt plaster very finely before use. Should it be a fact that even when thus treated old plaster fails to recover its normal setting properties, some other factor must be involved, and it would be worth while to determine the real nature of the changes which plaster undergoes when repeatedly gauged, set, and re-burned, using only distilled water in order to eliminate any influence of salts which might act as accelerators or retarders.

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DISCUSSION.

Mr. R. L. JOHNSON:—Dr. Desch stated that the volume of plaster after setting was less than the original. In practice, plaster during setting expands. If plaster is blended thin and run into moulds quickly there is less expansion than if blended thick; generally speaking, the greater the expansion the softer the mould.

Mr. W. EMERY:—I would like to ask Dr. Desch if he could tell me the approximate porosity of mixes made from the Estrichgyps to which he refers. He also mentioned during the lecture that he did not know that any work had been done on the addition of soluble salts to plaster to increase the porosity of moulds; it might interest him to know that several patents have been taken out embodying this principle, and references to two can be found in *Tonind. Zeit.*, (D.R.P. 144,141), **27**, 1903; *Sprech.* (D.R.P. 167,518), **39**, 1906.

I am glad the lecturer raised the question of fineness of grain. This factor is an extremely important one as regards the life of working moulds. America and Germany have adopted standard specifications for the fineness of pottery plaster, but I do not know of anything of this nature having been applied here in the Potteries.

If you break a new mould and examine a cross-section of it you find the working face to consist of a very thin film of solid or nearly solid plaster backed by a very porous mass containing numerous holes, varying in size from that of a pin point to that of a pin head. As the solid surface wears away these holes are exposed and pinholes are formed. Seeing that these holes are far more detrimental to the life of the mould than those produced by erosion alone, I should be glad if Dr. Desch would express his opinion as to whether these holes are air or water spaces, and also as to whether he can offer any suggestion as to the elimination of them, or alternatively the best means of increasing the thickness of the solid film.

Dr. J. W. MELLOR:—In frosty weather roofing tiles, flower pots and some terra-cotta are very liable to be shattered. There are some rather curious results, because with two flower pots of the same porosity one might break and the other remain intact. In the so-called freezing test for roofing tiles the goods are saturated with water, and subjected to alternate freezing and thawing a definite number of times, to find if the goods are likely to withstand the action of frost. It has been proposed to substitute for the process of freezing the crystallization of sodium sulphate or sodium thiosulphate, since those salts

crystallize in the pores of the ware and produce analogous effects.

Sodium sulphate was proposed for this purpose about 1823 by Vicat. The effect is rather curious on easy-fired glazed earthenware. If there is a slight imperfection in the glaze the solution gets into the biscuit and makes it rotten, and the thrust of the growing crystals in all those cases breaks up the body, sometimes making crystalline glazes. Metal-like crystals of rutile grow up above the surface of the glaze $\frac{1}{16}$ in. or more.

I do not think the rejuvenescence of plaster is quite so simple as it is supposed by the many inventors who have patented proposals to restore used plaster. If plaster of Paris is made up with distilled water and re-heated a number of times the setting qualities gradually deteriorate.

Dr. SCOTT said that he was glad that Dr. Desch rejected the theory that the variability of the behaviour of gypsum calcined at a high temperature was due to the existence of more than one form of anhydrite. Polymorphism, at the present time, is being somewhat overworked, both with regard to salts and metals, and it will probably be found that in many of the so-called polymorphic and allotropic forms, where there is no apparent crystallographic differences, the difference in properties is due merely to difference in grain-size. It is very probable that only one crystalline form of anhydrite exists, and that the rate of hydration depends, as it apparently does in the case of calcined magnesia, on the grain-size of the crystals.

The action of accelerators is generally explained as being due to the greater solubility of gypsum in solutions of these salts than in water, but it seems more feasible that an increase in the solubility of anhydrite would be a more important factor. Another possible explanation might be obtained from a consideration of the rate of precipitation of gypsum from such solutions; that is, practically, the velocity of crystallization of the gypsum. Likewise the effect of these salts on the rate of solution of anhydrite would constitute another factor.

Some accelerators not only shorten the time of setting but also increase the hardness of the product while others yield a softer product. An investigation of this point would be interesting, as no work seems to have been done on this subject. From a theoretical point of view, it might be ascribed to the effect of the accelerator on the habit of the gypsum. It might be expected that accelerators would also act as hardening agents as, with more rapid crystallization, there would be a greater tendency towards the formation of interlocking spherulites.

Mr. A. LEESE:—As a practical mouldmaker, I would say that in using plaster for moulds four things come into notice as being liable to cause trouble: large size of particles, smallness of particles, under-burning and over-burning. Large particles give slow setting, cause damage to the face of the plaster, and there is less expansion. Over-burning and over-grinding of the particles give a smothery touch and the face is easily rubbed off. There is also extra expansion and increased porosity.

By successively running one mould in another several sizes are obtained, and the difference may reach as much as $\frac{1}{8}$ in. in four or five runnings. Under-burned plaster gives the same trouble as with large particles, viz., slow setting, less porosity, hard to cut, and slight expansion.

In practice it is found there is a lot of expansion. If there were no expansion the mould would not deliver from a case which had straight sides or embossments upon it.

Prof. DESCH:—The question of expansion is one which I had tried to make clear, and the difficulty which some of the speakers appear to have found arises from the ambiguity of the term "expansion." That the external volume of the plaster mass increases during setting is well known, and the use of plaster in making moulds depends on that fact, since it is enabled to fill small details of the pattern. I wished, however, to distinguish between such an increase of external volume and a true increase of actual volume due to molecular rearrangement. The volume of the solid particles of plaster is less after setting than that of the dry plaster plus the water used in gauging. The apparent expansion is due to the outward thrust of the growing crystals, and is accompanied by the formation of cavities in the mass. It is on this porosity that the value of plaster as a material for moulds in, for instance, the casting process, depends. I was much interested in Mr. Emery's remarks. I have no information as to the porosity of Estrichgyps, but it must be much less than that of plaster of Paris, on account of the slow setting and the absence of rapid growth from a strongly supersaturated solution. I was not aware of the proposals to modify the porosity of plaster by the addition of salts, but it might have been expected that anything which affected the setting process would have some influence on the porosity. The small cavities in the porous part of the mould are due, I should say, to water and not to air. Would tapping the mould during setting perhaps eliminate them? I have not tried the experiment.

Turning to Dr. Mellor's remarks, I must confess that I am at a loss to explain the failure of the attempts to rejuvenate used plaster moulds by washing and re-burning. It might be expected that such a process, provided that the removal of soluble salts was complete, would restore the plaster to its original condition after re-grinding. A deterioration of setting qualities after gauging repeatedly with distilled water and re-burning indicates an unexpected influence of the past history of a mass of calcium sulphate on its properties which it is difficult to understand. The point deserves investigation, as a very interesting scientific problem is involved, in addition to the practical utility of a recovery process.

I agree with Dr. Scott that the idea of polymorphism has been overworked in explaining the behaviour of gypsum and other cementing materials. The influence of accelerators on other properties than the setting time, such as the hardness and porosity, certainly deserves to be investigated.

III.—Notes on the Refractory Materials of South Wales.

By J. Allen Howe,

Curator of the Museum of Practical Geology.

THE broad geological characters of the South Wales Coalfield are so well known that they require only the briefest notice. The Carboniferous rocks lie in the form of a large simple syncline or basin, broad in the east, narrow in the west, with the older members of the systems cropping out on the north, east and south.

The refractory raw materials of South Wales, silica rocks, fireclays and dolomitic limestones are practically all obtained from the Carboniferous strata; up to the present time the silica rocks are the most extensively exploited.

Silica Rocks.

To South Wales belongs the honour of being first in the field with silica bricks. It is almost 100 years since the first company was formed to make the now celebrated "Dinas" bricks. How completely this commodity established itself is shown by the wide-spread use of the term "Dinas." See, for example, this advertisement from a recent number of our enemy's *Tonindustrie Zeitung*.

> "Bedeutende sächs. Firma sucht für den Verkauf ihrer eigenen Produkte, als *Dinas*, Quarzit, Quarzsand, etc."

The name "Dinas" is derived from a rocky eminence, the Craig-y-dinas, situated not far from Hirwaun.

Silica rocks, that is quartzites, sandstones, grits or conglomerates, capable of being employed in the manufacture of silica bricks, occur at more than one horizon in this region, but the principal source of material is the Millstone Grit formation. This is divisible into three portions:—

(1) Farewell Rock, underlying the Coal Measures	0 to 450 ft.
(2) Middle or Shale Group, with occasional quartzites	100 to 1000 ft.
(3) Basal Grit, conglomeratic and fine-grained quartzites, grits, sandstones and thin shales	0 to 700 ft.

It is the lowest member or Basal Grit which alone is used for silica brick; there is abundance of material. On the north-western outcrop the three sub-divisions of the grit are most clearly defined, and the quartzite beds form well-marked ridges with a strong dip; on the north-central tract the dip is not so pronounced; on the north-eastern and south-eastern crops both the upper and lower sub-divisions may pass into shales. On the north side of the basin from St. Bride's Bay by Haverfordwest, Templeton, Kidwelly, Penwyllt, Hirwaun, Blaenavon to Pontypool, for a length of nearly 140 miles, the grit outcrop is almost unbroken

Within the Basal Grit the beds of stone are by no means constant in character. The type most in favour is a hard, compact, fine-grained quartzite with a buff, purple or blue tinge of colour; of these the buff or cream in some quarries and the blue in others is considered the best. This hard, fine-grained stone, may pass into one of a more friable nature or into one containing pebbles of quartz, varying in size from that of a pea to that of a hen's egg.

Thus, although the outcrop of stone is so extensive, much judgment has to be exercised in the selection of quarrying sites to avoid quarrying with an excessive amount of waste. Moreover the comparative inaccessibility of portions of the outcrop limits the regions of actual working to those spots that occur within reasonable distance of one of the numerous railways or manufacturing centres.

While the most favoured stone is the fine-grained compact variety the pebbly and loose sandy phases are not without their uses. In some cases a hard form of the pebbly quartzite is rejected, in others it is crushed along with the finer kind for silica brick; a certain amount of the incoherent grit may also be employed for the same purpose or for furnace sand.

From west to east silica rock is quarried in the following districts:—Templeton, in Pembrokeshire; Kidwelly, Llandybie, Brynamman and the Black Mountain, Penwyllt, Glyn Neath in the Vale of Neath, Hirwaun and Dowlais.

The stone is worked in open quarries except between Upper Cwmtwrch and Pontardawe, where the quartzite is obtained from boulders brought down by the River Tawe.

The rocks employed for silica bricks are fairly uniform in their microscopic characters. They consist essentially of angular and subangular grains with silica cementation. The grains in most samples average 0·1 to 0·2 mm. diameter, but in some they are smaller, 0·03 to 0·05 mm., and in others they are

slightly larger with occasional small pebbles of quartz and chert. A small amount of mica is present in most samples, and in some a very little felspar is observable. A little iron stain may exist between the grains of quartz and argillaceous matter in small amount is sometimes present.

The following analyses (B and C), made in the laboratory of the Geological Survey, illustrate the composition of representative examples of South Wales silica rocks. (A) is the analysis of a typical Sheffield ganister for comparison.

	A.	B.	C.
SiO_2	97·02	97·55	98·14
TiO_2	0·22	0·39	0·33
ZrO_2	0·18	0·03	0·04
Al_2O_3	0·34	0·72	0·42
Fe_2O_3	0·31	0·41	0·44
MnO	0·10	0·03	0·03
(CoNi)O	nt. fd.	nt. fd.	nt. fd.
BaO	nt. fd.	nt. fd.	nt. fd.
CaO	0·05	0·02	0·11
MgO	0·13	0·03	0·03
K_2O	0·09	0·23	0·10
Na_2O	0·17	0·12	0·11
Li_2O	nt. fd.	trace	trace
H_2O at 105° C.	0·02	0·02	0·01
H_2O above 105° C. ...	0·42	0·41	0·19
P_2O_5	0·02	nt. fd.	0·02
FeS_2	0·49	nt. fd.	nt. fd.
C	0·44	0·03	0·05
CO_2	0·04	0·03	0·06
	100·04	100·02	100·08

Silica rocks are employed by the following firms:— Abernant Dinas Silica Brick & Cement Co., Glyn, Neath; N. B. Allen & Co., Ltd., Hirwaun; A. Y. Dinas Silica Brick & Lime Co., Ltd., Mynydd-y-gareg, Kidwelly; Baldwins, Ltd., Landore; Black Mountain Silica Brick Co., Ltd., Upper Cwmtwrch; Brynamman Silica Co., Brynmman; Bynea Silica Works Co., Bynea, Llanelly; Guest, Keen & Nettlefolds, Ltd., Dowlais; J. B. Jenkins & Co., Neath; Lime Firms, Ltd., Llandybie; Penwyllt Dinas Silica Brick Co., Ltd., Penwyllt; Templeton Dinas Silica Brick & Cement Co., Glyn, Neath; Vale of Neath Dinas Firebrick & Cement Co., Glyn, Neath; H. & H. E. Smart, Kidwelly; Stephens & Co., Kidwelly; A. L. White, Morriston.

As examples of typical quarry sections we may cite the two following:—

Clegars Castle Quarry,

Two miles south of Narberth.

	ft.	in.
Quartzite, broken	4	0
Black shales	5	0
Quartzite, pale, current-bedded ...	10	0
Black shales	0	6
Quartzite, pale, fine-grained ...	9	0
Black shales	0	6
Quartzite, blue	6	0
Black shales	0	6
Quartzite, blue, fine-grained ...	5	6
Black shales		—

Garn-bica Quarry.

	ft.
Quartzite, thin-bedded (not used) ...	15
Black shales	3
Quartzite, thick-bedded	30
Black shales	1
Quartzite	9

At some works the black shales that come between the quartzite beds are calcined and ground to be added to the stone in the brick mixture; sometimes a small amount of the disintegrated rock which is found "pocketed" in the underlying limestone, in the condition of sand or grit, is added to the mix.

A sandstone of Triassic age, worked for various purposes on Stormy Down, near Pyle, Glamorgan, has recently been employed in silica brick making. It is rather friable and is not so free from felspar as the bulk of the silica rock used in South Wales.

Fireclays.

In South Wales and Monmouthshire fireclays are obtained solely from the Coal Measures; these are divisible into an Upper and Lower Series with a Middle or Pennant Series, chiefly sandstones, between them. Refractory clays are worked only in the Lower Coal and Pennant Series. Though fireclays are known in the Upper Coal Series and the Millstone Grit they are not at present exploited.

The seams of coal in this district are usually styled "veins"; they are very numerous and the majority have received distinctive names. These names are not always easy to correlate in different parts of the coalfield. The fireclays are commonly, though not invariably, associated directly with coal

seams. A knowledge of the relative position of the coals is necessary therefor for a proper understanding of the distribution of the fireclays. Full lists of the coal seams and their correlation cannot be given here, the subject has been fully treated in the Memoirs of the Geological Survey.

Although fireclays are widely distributed in South Wales, both vertically and horizontally, they are worked in comparatively few districts. The principal centres are:—Pontypool, Risca and Caerphilly on the eastern border; Beaufort on the north; Ystalyfera, Llanelly, etc., in the Swansea and Tawe Valleys; Brynamman, Ammanford, and Pontardulais in Carmarthenshire.

Monmouthshire and East Glamorgan.

Lower Coal Series: The following fireclays are now raised:—

(1) The Soap Coal fireclay, 8–9 ft. thick at Graigddu near Pontnewynydd, Pontypool, is employed for better class goods, together with a small amount of several other local fireclays.

(2) A clay about 45 ft. below the Soap Coal at Blaendare, Pontypool, is 5 ft. thick. It lies about half-way between the Soap Vein and the New or Elled Vein.

(3–5) Three clays respectively, 34, 27 and 21 ft. above the Elled Vein, at Ebbw Vale. The following section shows their position.

	ft.	in.
"No. 2 fireclay" (working) ...	2	6
Black shale (working)	3	0
Shale	1	6
Coal	0	8
"No. 1 fireclay" (working) ...	2	0
Rock	0	8
Rashings	0	4
"Elled fireclay" (working) ...	5	0
Thin sandstone	21	0
Shales		
Elled coal	—	

(6–7) The Red Vein fireclay and Big Vein fireclay at Wernddu, near Caerphilly. The quarry shows:—

	ft.	in.
Sandstone and shale	40	0
Red Vein coal	4	6
Fireclay, impersistent ..	9	0
Shale (for red brick) ...		

(6-7) *continued.*

	ft.	in.
Big Vein coal	6	6
Fireclay	4	0
Shale (for red brick)	50	0
Black Vein coal	4	0

When the Red Vein clay is obtainable it is mixed with the Big Vein clay.

(8) A fireclay 8 ft. above the Old Coal at Beaufort, near Ebbw Vale. The beds seen in the quarry are:—

	ft.	in.
Yard Vein coal	7	10
Shale and clay	24	0
Little Vein coal	1	0
Buff clay	0	9
Fireclay	6–10	0
Rock	8	0
Old Vein coal	4	6
"Ganister," a siliceous fireclay ...	2	0
Clay		—

The shale beneath the Yard Coal is used for red bricks, the clay for sanitary pipes.

(9) Fireclay from within the Old Coal, worked in the Pontnewynydd district. The Old Coal usually consists of an upper and lower coal seam separated by the Old Coal fireclay, which is 3–4 ft. thick at Llantarnam, 5–8 ft. at Henllys, and 2 ft. at Pontnewynydd. At the last-named place a 6 ft. clay above the Old Coal is also worked; the two clays are mixed together At Henllys the fireclay passes laterally in places into a hard, fine-grained quartz rock. For special purposes the better parts of the bed are selected.

(10) The Old Coal *underclay*, a so-called "ganister" (see No 8 above) is worked at Trefil, near Ebbw Vale. Here the Old Coal fireclay is represented by 18 in. of "clod" The "ganister" consists of the following three beds:—

	ft.	in.
Top bed, dark fireclay	0	9
Middle bed, hard, grey siliceous fireclay	2	3
Bottom bed, hard, darker siliceous fireclay	1	0

(11) A "No. 5 Fireclay" (relative position uncertain) is worked at Darren, near Risca. This clay is about 6 ft. thick; the upper half, of "best quality," is employed for higher grade goods; the lower half is of "second quality." Other clays on the property are associated with the Brass, Thick, Grey, Red, Pontymister and Rock Veins. The last is a siliceous clay.

Llanelly and Swansea District.

In the Llanelly and Swansea district fireclays are raised from the Pennant Series (see page 36) as well as from the Lower Coal Series. In approximate descending order the principal clays exploited are:—

In the Pennant Series.

(12) Clays 35 to 40 ft. below the Five Feet Coal at Morriston, near Swansea; these include a "soft blue" for terra-cotta facings, and a "hard blue" for brindled bricks and acid-resisting ware.

(13) The Graigola (Six Feet or Fiery) Vein fireclay at Clydach, Pontardawe and Glais in the Swansea and Tawe Valley. A black clay that weathers brown, average thickness 3 ft.

(14) Fireclay beneath the Golden Vein, worked near Pontardulais and Bynea, is from 3 to 5 ft. thick.

(15) A fireclay associated with the Gyscwm Rider Coal at Pembrey.

(16) Two clays below the Black Rock Coal at Pwll and Trefig, Llanelly. The upper is 2 ft. 9 in. thick; the lower, which is blacker and harder, is 5 ft. thick.

In the Lower Coal Series.

(17) Shales about 200 ft. below the Red Coal at Cwmgors near Brynamman. These are 40 ft. thick, they are ground for ladles.

(18) A clay 30 ft. below the Red Coal at Cwmgors.

(19) The Pencraig (Little or Lower Four Feet) Vein has fireclay and shales below it at Lower Cwmtwrch.

The quarry shows:—	ft.
Thin coal	3
Fireclay (for firebricks and steel ladles)	9
Blue shale (for steel and spelter works)	16
Rock	7
Shale (for steel and spelter works) ...	30

(20) A clay 51 to 54 ft. below the Rocket Coal at Pontyclerc, Ammanford. The bed is 5 ft. 6 in. thick, but only the upper 2 ft. 6 in. is employed.

Besides the fireclays enumerated above there are many that have been worked a little from time to time, and others that have never been worked are recorded in coal-mine sections. Some of these clays are briefly mentioned below.

Newport District.

In connection with one of the several Rock Veins a fireclay has been worked in the valley east of Twyn Barllwm.

At Darren, near Risca, a 2 ft. siliceous clay lies below the Brass Vein Coal, and a similar clay occurs lower down, beneath the Hard Vein (? Old Coal of Cwm Brân). The Brass Vein Clay of Machen, 4 ft. thick, is reported to have made good firebricks. Some of the conglomeratic quartz grit from above the Rock Vein was mixed with it. These two clays, the Brass and Hard Veins, have been worked also at Rudry. Two fireclays, respectively 2 ft. 3 in. and 5 ft. 6 in. thick, lie between the Big Rock Vein and Big Vein Coals at Rudry shaft, probably above the Limog Vein Coal. The principal coal seams in this district are, in descending order, the Little Rock Vein, Big Rock Vein, Bowder Vein, Limog Vein, Yard Vein, Red Vein, Big Vein, Black Vein, Fork Vein, Brass Vein, Hard Vein, Sun Vein. The best clays appear to be associated with the Big, Limog and Brass Veins; the less good clays accompany the Little Limog and Hard Veins.

At the Navigation Collieries, Argoed, at 290 yards, we find beneath the Brithdir Coal:—

	ft.	in.
Fireclay	7	0
Hard White Rock	8	0
Fireclay	3	0

In the Rhymney Valley, at Bargoed Colliery, the Rhas-las, or Black Vein is underlain by:—

	ft.	in.
Fireclay	12	0
Coal	1	0
Fireclay	2	0

and at 600 yards in depth we find:—

		ft.	in.
Coal		—	
Fireclay		9	0
Cleft		24	0
Red Vein	Coal	2	8
	Fireclay	3	0
	Coal	1	0
Fireclay		6	0

At Groesfaen Pit in the Rhymney Valley is a fireclay 10 ft. thick above the Brithdir Vein, at 53 yards from the surface.

In the Aber Valley, at Windsor Colliery a fireclay 12 ft. thick occurs 41 yards below the (Rhondda No. 3?) coal.

At Llys-pen-twyn Pit, in the Blackwood and Pengam basin, is a fireclay 4 ft. thick at 25 yards from the surface, separated by 12 ft. of measures from another fireclay below, that is 9 ft. thick.

Near Risca a fireclay 2 ft. 6 in. thick, beneath the Sun Vein in the Millstone Grit Series, was formerly worked along with the accompanying shales.

At the Furnace Blwm Brick Works, at the west end of Caerphilly Common, the best clay, 2 ft. 6 in. thick, was said to lie below the Hard Vein. A clay below it, said to be indistinguishable from it, at sight, was formerly mixed with it, but was found to be injurious. This lower clay contained only 16 per cent. of silica The clays of the Brass and Limog Veins were also used here for pipes, tiles, bricks terra-cotta, etc.

At the Bryn Coch Brick Works, Taff's Well, the following clays are met with in descending order :—

A fireclay suitable for common bricks, 4 ft. thick, above No. 2 Coal.
A fireclay of good quality, 2 ft. thick, beneath No. 2 Coal.
An inferior fireclay beneath the Limog Coal.
A good fireclay beneath the Brass Vein, 5 ft. thick.
A good fireclay beneath the Hard Vein, 3 ft. thick.

Pontypridd District.

On the south crop, in the Bryncethin and Ogwr Valley, a fireclay under the Rock Fawr Coal is said to make a good firebrick. A fireclay floor lies under the Nine Feet or South Vein, and another lies under the Cribbwr-Fawr Vein ; the latter is rather variable in character.

The underclay of No. 2 Rhondda Vein has been worked for bricks at Victoria Works, Gelliwion Wood, near Pontypridd, and thick clays associated with what is probably the same seam have been got in an open pit on Mynydd-Brithweunydd, near Llwyn-y-pia. Firebricks have been made at Ty-Cribwr, one mile west of Aberkenfig, from beds beneath the Cribbwr-Fawr Vein.

At Bryncethin, east of Tondu, common red bricks and buff firebricks have been made on a large scale from beds in the higher part of the Lower Coal Series. The Graig Vein, at Abercwmboi, rests on a fireclay used for a buff brick.

In the Upper Coal Series there is a red fireclay below No. 1 Llantwit Vein at Ystrad-barwig Colliery.

In the Pennant Series the Cillydu Vein rests on a good fireclay near Afonkenfig.

The Millstone Grit conglomerate from Aberkenfig along the top of Pennsylvania Wood is overlain by coals and a fireclay that has been used for bricks.

Abergavenny District.

A 2 ft. fireclay occurs in the Millstone Grit of Lammarch Dingle.

At Aber-Gwerelech, in the Merthyr Tydfil district, the following clays may be noted in the Lower Coal Series :—

	ft.	in.
Good fireclay...	5	6
Fireclay	4	0
Measures, with Three Pins Mine	—	
Good fireclay...	4	0
Measures	—	
Blewers Coal	—	
Fireclay	3	0
Measures	—	
Fireclay	2	0

Ammanford District.

At the Neuadd Colliery, beneath the Trigloin Vein, there is 5 in. of very soft clay succeeded by 4 ft. of hard fireclay.

At Pontyclerc the fireclays underlying two thin coals have been used. The Lower Freclay Vein is probably the Upper Triquart or Gras-isaf Vein.

A fireclay between the Big Vein and Charcoal Vein was employed for firebricks at the Old Gors-goch Colliery.

Carmarthen District.

The underclay of the Upper Felen or Yellow Vein was formerly worked in drifts about the northern or Afon-Hafren dingle or Ynys-Hafren. The section shown was:—

	ft.	in.
Rock	4	0
Cliff	4	0
Upper Felen Coal	1	8
Fireclay	3	0
Shale	—	

The Low Vein (here only a smut) overlies fireclay visible in the brook 100 yards east of Cae'r-clovers, Pont-Henny.

At Cwm-bâch Colliery, near Pont-Yates, a 7 ft. fireclay occurs below the Rhâs-fâch Vein. The upper half has been worked for bricks and for lining furnaces.

A fireclay underlies a coal above the Carway-fawr Vein at Gelli-gelynog; it is 8 ft. 6 in. thick, with balls of ironstone in the lower part.

The Green or Wyrdd Vein, worked at Trimsaran, has a fireclay floor.

In the Pennant Series, the Brondini Vein underclay has been used, together with the shales above, for brick making.

Swansea District.

In the Pennant Series a 6 ft. fireclay occurs between the Hard Vein and the Granway Vein at Gnoll Colliery. The Wernffrenth Coal is split by a 3 ft. 6 in. fireclay in the Primrose shaft, and lower down in the same a 6 ft. bed overlies 20 ft. of rock on top of the Graigola seam. West of the Tawe, at Guret's Colliery, the Graigola seam has a 3—5 ft. fireclay beneath it.

At Saints' Pit both the Three Feet Vein and Two Feet Vein rest upon fireclays, each about 3 ft. thick. Between the Two Feet and the Jenkin Veins there is a great body of shale, in which, below the former vein, there is a bed of red and mottled fireclay, worked for firebrick at Bon-y-maen, Morriston and elsewhere.

At Morlais Colliery, Llangennech, a 9 ft. fireclay occurs beneath the Llangennech Four Feet (Swansea Five Feet) Vein.

West Gower and Pembrey District.

The Little Pwll or Clay Vein is worked near Stradey Lodge; both clay and coal are extracted; the fireclay is about 3 ft. thick.

At Cwm Capel Colliery the clay pit showed 20—30 ft. of shale over a coal with 10 ft. of underclay.

These short notes can do little more than indicate that we have in South Wales a great number and variety of clays—there are scores of others to be found in the mine records that have not been mentioned above. Yet, in spite of this seeming abundance, how little do we know of the great bulk of the material. Much of it may be unusable, some may be too difficult of access, but there may be one or two which may be invaluable.

It should be one of the first duties of the Refractory Section to give encouragement to any good working scheme for the

collection, formation and distribution of exact data relating to as many as possible of the raw clays.

Dolomite.

In connection with changes in the steel industry the question of the supply of dolomite has recently acquired importance. A word or two on the possibility of meeting a demand for this material in South Wales may not be out of place here.

Dolomitic limestone occurs fairly abundantly in the Carboniferous Limestone Series of South Wales. This series constitutes the lowest member of the Carboniferous system, it appears therefore cropping as the outermost rim of the basin, beneath the Millstone Grits and Shales.

Though with the exception of a few breaks, the limestone crop is continuous on the north, east and south, it is only in certain portions that the amount and quality of the dolomitised portions are sufficient to merit consideration as a source of "basic" material.

On the north crop dolomite is well developed only about Clydach near Abergavenny, where it occurs, much of it very pure, in association with the faulting of the strata.

In the south-eastern part of the crop between the Taff Valley, near Cardiff and Pontypool, a great deal of the limestone is dolomitic. At Taff's Well, for instance, the lower half of the Main Limestone, 300 to 400 ft. thick is dolomitised, some of it to a high degree. At Machen nearly all the visible limestone is dolomitic, and at Risca, where it is 675 ft. thick, it is almost wholly dolomitic.

On the south-western portion of the outcrop, in the Gower peninsula, dolomite is fairly abundant in the cliffs between Pwlldu and Mumbles Head, and again in Langland and Caswell Bays, also between Rhossili and Worm's Head and near Port Eynon. It is also found in several places near Pembroke Dock.

The difficulty in South Wales is not to find dolomite but to find it in places where transport facilities are favourable and where it can be quarried in a straight-forward way. The liability of beds of dolomitised limestone to change rather rapidly from point to point in composition, and especially in silica content, makes it absolutely necessary to carry out a chemical survey of the beds in a probable quarry site before launching out into extensive operations. When good beds occur mixed irregularly with poor beds quarrying is likely to be troublesome.

DISCUSSION.

Prof. FEARNSIDES, as a visitor from another district, expressed his appreciation of Mr. Howe's concise summary account of the geological distribution of refractory materials in the South Wales Coalfield. In the paper before them it had been made clear that among the Carboniferous rocks of the South Wales district there is a plentiful supply of high-class refractory rocks, but from what Mr Howe had said it would appear that during their comparatively recent revision of the 6 in. maps of the coalfield, the officers of H.M. Geological Survey had no instructions and therefore no opportunity to determine exactly either the refractory qualities, the relative worth, or the lateral extent and geological distribution of those individual beds of rock which have a special economic value.

In commenting thus upon the present lamentable lack of available information respecting these essential items of the nation's mineral wealth, the speaker wished to make it clear that he was bringing no allegations of inefficiency against any officials of the public service to which Mr. Howe belonged, and suggested that the remedy rests with the Government, which, being both the mouthpiece and pursekeeper of the tax-payer, and also the paymaster of the Geological Survey service, should forthwith augment its technical staff and laboratory accommodation and issue the necessary instructions to ensure that such work of vital national importance may proceed. He suggested that users and makers of refractory materials in the South Wales district together should make this known to their local members of Parliament, who if they were persuaded to understand the position, would not be long in providing the required remedy. The Refractory Materials Section of The Ceramic Society was doing good work in impressing upon its public the urgent need for more and better information concerning the mineral resources of the industrial districts where its meetings are successively held.

Looking through the paper before them for facts which have not previously been put on record, the speaker drew attention to the scientific interest of the three complete analyses of silica rocks quoted on page 29, and asked if Mr. Howe and Dr. Mellor would arrange for the micro-photographs of slices cut from equivalent rock samples to be incorporated with the paper as it appears in the TRANSACTIONS. He commented particularly upon the circumstance that, though absent in the Welsh rocks, the analysis of Yorkshire ganister indicated the presence of an appreciable proportion of sulphide of iron. In the opinion of the speaker the presence of this small amount of iron

sulphide, which is characteristic of much of the blue ganister obtained by mining in the Sheffield district, is very useful to the makers of silica bricks, because as a substance which reacts with silica at temperatures round about 1,000° C., it helps to start off the inversion of the quartz and so assists in keeping the coal consumption at the kilns comparatively low. Mr. Howe had mentioned that in South Wales compact quartz rock which is blue and unweathered is accounted by the brickmakers a material quite distinct from the softer and partly weathered yellow rock. The speaker having in mind the considerations above indicated, asked whether the blue rock ever contains any appreciable quantity of iron sulphide and, if it does, whether in works where both and blue rock is employed, manufacturers had noticed any difference in the quantities of coal needed to burn off satisfactorily the two kinds of rock.

Mr. L. SOUTHWOOD JONES:—Just a few words about the South Wales dolomite. I happen to have made a few experiments. In the very early days of the war, and in my colossal ignorance I lined a cupola furnace for calcining dolomite with a firebrick lining, and of course it was absolutely fatal. I then tried to get magnesite bricks, but it did not come off. After that I lined the cupola for about 4 in. to 5 in. with calcined dolomite, the top being firebrick. The result was that the calcination took place mainly on the top of the cupola and the firebrick lining went again. The bulk of the product was ruined by the fused firebrick. Mr. Howe says that the chief difficulty seems to be the distance the dolomite is from the railway. In the dolomite I have in view that difficulty does not occur, but there is another difficulty in which perhaps scientific gentlemen might help us, and that is, in the beds I am acquainted with you get low and high silica beds close together and indistinguishable; for example, 0·1 silica up to 5 per cent. I suppose the 0·5 per cent. is too low to sinter properly. Our difficulty will be to get someone to tell us how we can work the low silica and leave the high silica. I venture to ask that somebody will give us some hints as to how that may be done.

Mr. P. N. F. SHEPPARD:—As a matter of fact, I may tell Prof. Fearnsides that in our opinion the blue takes more firing than the other.

Mr. H. M. RIDGE:—In the first place I hope that Mr. Howe will not feel at all annoyed if I suggest the desirability of stating with the three analyses the exact source of the samples *B* and *C*. He stated they were typical examples, but the greatest possible accuracy is desirable for such references.

I would also like to ask whether he is not able, in connection with the section he is giving us of the various shales, to say something of the analyses of these black shales. Could he not also supply a bibliography of the refractories of S. Wales? I have had difficulty in finding these literary references.

Then he refers to the materials in the lower coal series and especially to a blue shale used for steel and spelter works. Would it be possible to supply analysis, local name, and precise source of that material?

On page 35 he refers, in connection with the Newport district, to a lower bed of clay which contains only 16 per cent. of silica. I take it that it is a fireclay. What is the balance of the material, is it high in alumina? If there is a refractory high alumina clay in S. Wales it would be of great importance to the industry. What is the analysis of the dolomite? This might also be useful.

I would like to refer to a serious defect from the users' point of view. When I first came to the Swansea district, many years ago, I was told I must bring in all my firebricks from England if I wanted them to stand in zinc distilling furnaces. No one was apparently able to put me in touch with local makers of high class firebricks. After a number of trials I myself found and satisfactorily used some material which in refractoriness and lasting qualities is as good as anything which I have been able to obtain on the other side of the Severn, and I have had excellent material from Mr. Southwood Jones.

Mr. COSMO JOHNS:—I am glad that Mr. Howe took up that question of the German authority who dogmatise on the manner of testing good and bad, and I am glad that he went to Penwyllt to take his type. Penwyllt can be taken quite fairly as a typical section, and there we see the German has dogmatised a little bit too much. Mr. Howe will know quite well that I am not criticising him at all when I make a reference to the omission from that note. In the last few days I have visited many works in this district and I have learned how little is known in the district of what has been published, and further, what is perfectly clear, the very small amount of work that has been done in making known the wonderful resources of the district. If I may offer advice, it is that this district should not wait for The Ceramic Society to move in the matter, but that this district—manufacturers who are interested and users—should make a demand on the Government for the survey of the mineral resources of the district and not wait for The Ceramic Society. The demand should be made with intelligence, and

the less delay the better, and leave it to the officers of the survey to do their work. They are keen to do it, and will do it efficiently, provided you ask for it.

When I say mineral resources, I am led to think of a problem which will be a more pressing one soon, and that is the lack of limestones. I am certain they are abundant.

I do know of a case where, possibly in ignorance, it is being used, causing extra expense and delay in metallurgical operations in this district.

You should apply pressure, and it can only be done by some order from the Government. Also for all sections that are worked a record should be kept when for a commercial reason they are left alone.

Mr. J. ALLEN HOWE:—Prof. Fearnsides has pointed out the significance of the small amount of iron sulphide in the analysis of blue Sheffield ganister. I think he may be right, although the experience of Mr. Sheppard does not confirm the view that the blue stones fire at a lower temperature than the others. I should say, however, that we have not found iron sulphide in all the Sheffield ganisters we have analysed, in fact we have not found it as a rule, in the ganisters and silica-rocks except in a few from the Sheffield area and a few from Scotland. We may assume that at present the majority of silica-bricks both in the United Kingdom and in America and Germany are made from materials in which the content of iron sulphide is negligible.

I entirely agree with Mr. H. M. Ridge in his desire to see the exact source of the material given with the published analyses. The two analyses mentioned in the paper were introduced merely to show the resemblance between a typical South Wales silica-rock and a typical Sheffield ganister, and on this occasion I wished to avoid precise allocation of the samples for reasons which I believe will appeal to many of the gentlemen present. These analyses and others will shortly be published with full particulars by the Geological Survey and original samples may always be inspected at Jermyn Street.

Mr. Southwood Jones has touched upon the difficulties in quarrying dolomite to which I have referred in the paper, page 37. What he says is particularly true of the dolomite of South Wales. I am aware of no method of getting over the difficulty beyond what I have already suggested.

Professor Fearnsides, Mr. Ridge and Mr. Cosmo Johns have all dealt with the need for more exact information respecting our supplies of raw refractories. Speaking now of fireclays, there is an immense amount of leeway to make up.

Mr. Ridge has asked for a bibliography of the clays of South Wales—there is no material for a bibliography; the original papers have yet to be written. We know next to nothing of the comparative qualities of the clays already in use in South Wales, and nothing whatever of scores of other clays that exist here. South Wales is not peculiar in this respect.

Most of the fireclays now in use have come into service more or less by accident. What we require now is an inventory of our *unused* clay beds accompanied by a record of their individual qualities. This can be secured only by an examination of their outcrops and by the compulsory preservation of samples and data obtained in making new borings and shafts. Such information should be kept in a central institution available to all enquirers. Much of the information when gathered would be of negative value, but it would be valuable none the less, and eventually when clay of a certain type was required the manufacturers would know where to look for it with reasonable certainty of success. This is a matter which concerns other industries besides the makers of refractory ware. The accumulation of this data must necessarily be slow, it involves prolonged work in the field, analyses by the chemist, firing tests and other tests by a competent authority under standard conditions. All this will take time and money and co-operation. Speaking on behalf of the Director of the Geological Survey, I may say that he is most anxious to take his proper share in this work and to co-operate with any responsible organisations working toward the same end. Already Dr. Mellor and his staff are acting in conjunction with the Geological Survey in examining the fireclays, and the results will be made public as fast as the size of our staff and our numerous details will permit. But to make a good job of it we need all the guidance and support we can get from all sides, and one may reasonably look to the Refractory Section of the Ceramic Society to take the lead.

IV.—Refractories in the Zinc Industry.

By J. A. Audley, B.Sc.

IT is intended in this paper to discuss only the refractory materials concerned in the production and use of vessels for the distillation of zinc, and only incidentally to make any reference to the refractories employed in the construction of the furnaces.

In passing it may be recalled that as far back as 1743 a zinc factory was erected by Champion at Bristol, and others appeared later in the United Kingdom. The foundation of the extensive zinc industry of Silesia was laid in 1799 by Ruhberg, who had studied the process in England. The Belgian zinc industry began ten years later, and it was not until 1850 that zinc smelting began in the United States.[20] It looks like another case of an important industry languishing, or at any rate lagging behind, for reasons which can scarcely be considered as satisfactory, though the Swansea district at least has kept moving.

As is well-known to those in the industry, the ordinary method of extraction of zinc from its ores depends on the conversion of the zinc compounds (if necessary) into oxide or silicate, and on the subsequent reduction of the oxide or silicate. In the case of the native carbonate of zinc a simple calcination converts it into oxide, whereas the more abundant blende or zinc sulphide requires roasting with free access of air in order to convert it into oxide. For the reduction of the calcined ores they are heated with carbon (usually coal crushed small) to a white heat, generally in retorts or muffles made of fireclay. The zinc is liberated as a vapour, which is collected and condensed in other clay vessels (receivers or adapters) at a lower temperature. Faulty calcination of the zinc blende may leave small quantities of zinc sulphide or zinc sulphate mixed with the oxide, and various other metallic compounds, etc., may be present as impurities derived from the ores. If iron be present, any sulphur also present combines with it, but iron sulphide is objectionable because it corrodes the retorts or muffles. Zinc silicate can only be reduced by solid carbon, giving zinc, carbon monoxide, and silica, but zinc oxide can not only be similarly reduced to give the same products minus the silica, but it can also be reduced by carbon monoxide with formation

of carbon dioxide. This latter is immediately reduced to carbon monoxide by the excess of carbon present, so that it is unable to re-oxidize the zinc vapour, as would happen at a red heat in the absence of the carbon. The gas escaping from the reducing apparatus after distillation has commenced has been found to contain only very small quantities of carbon dioxide, rarely exceeding 1 per cent., and often much less. The reaction between zinc and carbon ordinarily takes place at about 1,050° C.[20] and the maintenance of retorts at this high temperature necessitates a high consumption of fuel. Iron compounds may be very injurious, ferric oxide being reduced to ferrous oxide, which combines with any silica or acid silicates present to form slags. Ferrous silicate readily combines with other silicates to form easily fusible double silicates, and is also capable of dissolving the silica and silicates of which the retorts, etc., are commonly made, thus actively assisting in their destruction. They also spread over portions of the charge, preventing reduction, and so increasing the amount of zinc in the residues. Basic iron slags take up oxide of zinc, and preserve it from reduction. In the absence of silica, metallic iron is reduced from iron oxide and from basic iron slags, and the iron so liberated will decompose sulphides to form iron sulphide. Manganese silicate forms a very fluid slag, and lead silicate even more so. Calcium silicate (silicate of lime) is not easily fusible by itself, but produces fusible double silicates with ferrous silicate or manganese silicate. The case is much the same with magnesium silicate. Lead silicate is not easily formed, owing to the ready reduction of lead oxide, so that under normal working conditions the danger from this source is slight.

The charges are prepared by mixing or grinding together the ores with the coal used for reduction. Formerly lime also was added to zinc silicate, but because of the tendency to produce easily fusible double silicates this practice was discontinued. It is of advantage to combine the available ores so as to obtain a purely siliceous or purely basic grade as far as practicable, or, failing this, to mix so that the bases and the silica shall form a slag as difficultly fusible as possible at the reduction temperature of the zinc. Thus, much lime, or (better) lime and magnesia, or alumina, may be combined with very little silica, or much silica may be present with only small quantities of bases. In the presence of silica the most injurious substances are the oxides of manganese, iron, and alkalies, or considerable quantities of lead in the ores. When these are present their effects should be diminished by adding zinc ores

free from iron, manganese, or lead. Excess of reducing agent is mixed with the prepared ores, and for this purpose is used lean (or non-gaseous) coal, which should be practically free from pyrites and shale; instead of the coal is sometimes used carbonised coal ("cinder"), or small coke, or a mixture of raw and carbonised coals. It is necessary to have excess of the reducing agent, in order to ensure intimate contact with the ore, and to produce carbon monoxide, which prevents entrance of the oxidizing furnace gases through the pores of the retort walls, and also drives the zinc vapour into the condensers and at the same time prevents air from entering them.

The receivers, not being exposed to the full heat of the furnace, are made of a less refractory material than the retorts and muffles.

The retorts or muffles are made of a mixture of raw fireclay and burned clay or clean fragments of old retorts; it is more resistant to fluxes the higher the ratio of alumina to silica, and accordingly the addition of coarse-grained quartz (as in Upper Silesia) to the retort mixture has not proved successful even with basic charges. The great objection to the ordinary mixtures is that clay is a bad conductor of heat, and will not stand great fluctuations in temperature, that it is attacked by material in the charge, and that its porosity allows zinc vapour to escape.

In Upper Silesia the muffles are made of clays from Saarau, Mirow, and more recently from Briesen near Lettowitz (Moravia), which is remarkably refractory. Clay from Striegau, mixed with sandy clay from Grojec or with kaolin from Saarau, Pentsch, Ruppersdorf, Göppersdorf, and with broken retorts and Neurode slate, is also used.

The Briesen clay, which is in the form of hard lumps, is broken into grains about $^1/_{25}$ inch in size, and allowed to stand in a moist condition for some months. It then forms an excellent material for the preparation of muffles. Clay from Striegau (9, 10, 11)* is more readily affected by fire than Saarau clay, but both these, like Briesen clay, shrink considerably. Grojec clay (12) is used in the crude form, and is unshrinkable, but as it melts at a white heat it can only be used in small quantities mixed with other kinds. The Silesian kaolins (13, 14, 15, 16), shrink on heating until the combined water is expelled, and later expand because of high content of quartz. The Neurode shale forms the best addition to the clay used for muffles in Upper Silesia, being cheaper and more refractory than fireclay.

* The numbers refer to the table on next page.

Schnabel[17] quotes the following analyses of clays and shales given in the Table:—

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Loss on Ignition
Saarau ... (1)	49·00	36·75	0·80	—	0·56	0·41	0·37	11·87
,, ... (2)	50·41	32·66	3·23	0·50	—	1·56	—	11·64
Briesen ... (3)	44·76	39·25	0·48	0·26	0·36	1·55	—	13·41
,, ... (4)	44·88	39·93	0·99	0·21	0·08	0·52	—	13·03
,, ... (5)	45·46	39·00	0·01	—	trace	—	—	14·26
,, ... (6)	44·64	39·60	0 01	—	trace	trace	trace	14·96
,, ... (7)	44·87	39·76	1·14	0·76	trace	0·67	—	12·95
,, ... (8)	45·61	39·31	1·13	0·37	—	0·66	—	13·25
Striegau ... (9)	68·00	27·00			5·00			—
,, ... (10)	53·86	29·00	1·81	0·46	—	—	—	14·87
,, ... (11)	58·02	29·65	8·40	1·15	0·78	0·55	—	10·91
Grojec ... (12)	65·39	22·72	0·91	—	0·28	0·86	1·84	7·77
Pentsch ... (13)	57·59	29·33	2·60	0·74	0·26	—	—	9·33
Ruppersdorf (14)	61·60	27·23	1·24	0·38	—	—	—	9·61
,, (washed and burned) (15)	54·70	43·00	1·70	0·30	—	0·30	—	—
Göppersdorf (dried at 100°) (16)	49·42	36·69	0·73	0·09	trace	0·43	—	12·70
Andenne ... (17)	49·64	34·78	1·80	0·68	0·41	0·41	—	12·00
,, ... (18)	57·95	29·53	1·88	1·72	0·36	—	—	8·45
,, ... (19)	73·58	17·62	1·29	1·24	0·40	—	—	5·50
Namur ... (20)	71·79	19·49	0·85	—	0·06	0·85		7·47
Neurode shale (crude) (21)	43·84	38·30	0·46	0·19	0·19	0·42	—	17·78
,, (burned) (22)	55·73	42·69	0·27	0·28	0·23	0·50	—	0·43
,, ,, (23)	54·00	44·92	0·80	0·48	trace	0·60	—	—
Rakonitz shale (burned) (24)	52·50	45·21	0·81	—	0·54	0·51	—	0·78
,, ,, (25)	51·87	46·39	0·52	—	0·45	0·32	—	—

In (1) and (2) 14 per cent. of the silica is in the form of sand.

The following composition is given by Schnabel[17] for the better qualities of fireclay used in Belgium for the manufacture of tube-retorts:—

	SiO_2	Al_2O_3	Fe_2O_3	CaO	Water
Andenne	54	26	2	—	20
Namur	63	24	1	1	11
Natoye	71	20	2	—	7
,, ...	76	18	trace	—	6

He also gives analyses of certain varieties of clay used in the U.S.A.[17]

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2	Loss on Ignition
Woodbridge ...	42·85	37·32	1·18	1·48	0·41	0·76	—	—	16·36
,, ...	42·83	37·01	1·04	1·41	0·46	0·85	—	—	16·27
Cheltenham ...	50·19	30·08	2·79	1·31	0·47	0·65	—	—	14·65
,, ...	50·16	30·47	2·48	1·51	0·29	0·97	—	—	14·62
St. Louis, Mo...	50·80	31·53	1·92	—	—	0·40	—	1·50	13·80
Perth Amboy, N.J. ...	46·90	35·90	1·10	—	—	0·28	0·16	1·30	14·30

The St. Louis clay contained 12·70 per cent. of the silica as free quartz, and the Perth Amboy clay 6·40 per cent.

E. M. Johnson[9] gives other analyses of American clays, which can be referred to in the abstract.

Schnabel[17] quotes the following analyses of old broken retorts :—

		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	ZnO	CdO	MnO	K_2O+Na_2O
elgian retorts (blue pieces)	(1)	41·13	33·48	2·84	0·92	0·47	21·47	—	0·37	—
elgian retorts (white pieces)	(2)	50·10	38·28	3·42	1·13	0·73	6·10	—	0·41	—
ixtures of ground fragments from several works in Upper Silesia ...	(3) (4)	50·20 48·64	0·61 0·73	30·80 33·58	0·48 0·35	0·56 0·39	17·64 16·38	0·005 0·07	— —	0·21 0·30
verage Analyses for 1885-1900 of retorts from works in Upper Silesia ...	(5) (6)	46·50 52·14	36·84 25·56	1·21 0·75	0·60 0·40	0·41 0·35	14·11 18·21	0·08 0·01	— —	0·25 —
etort from Godulla Works, Upper Silesia	(7)	49·75	31·82	0·96	0·52	0·38	16·63	0·13	—	0·80

The charge is generally basic, so it is mostly preferable to use for making the retorts, etc., a highly aluminous material comparatively poor in silica.

The chief requirements of a zinc retort include refractoriness, resistance to dust and slag, mechanical strength and tenacity, resistance to sudden temperature changes, low degree of permeability to zinc vapours, minimum contraction in the fire, and durability. In practice great influence is exercised by the process of preparing the mixture.

In Silesia the mixture is composed of two volumes of raw rich clay (Briesen, Saarau, or Striegau, or mixtures of these), one of raw sandy clay (Striegau clay, or Silesian kaolin,

or mixtures), and five of other materials. The latter are powdered fragments of old retorts and burned Neurode shale, mixed in different proportions. The size of the clay grains is from $^1/_{25}$ to $^3/_{25}$ inch. The retort fragments and Neurode shale range from dust up to $^2/_5$ inch in diameter. The larger pieces increase the strength of the muffle and make it more resistant to temperature changes and chemical erosion.

In Belgium the proportions vary much. In some works 40 volumes of rich raw clay, 50 of burned clay, and 10 of coke are used. In other works the corresponding figures are 36, 54, and 10 respectively, and in still other cases the proportions are 30 of rich raw clay, 10 of sandy clay, 50 of retort fragments, and 10 of coke. Another Belgian composition is 10 of raw clay, 10 of burned clay, 8 of retort fragments, 1 of quartz, and 0·5 of coke. Coke, added to the mixture for making retorts or muffles, improves the refractory qualities of clay, and reduces shrinkage.

Mühlhæser[14] gives as a suitable composition in America, 44 parts of dry St Louis clay and 56 parts grog (chamotte) to be ground together, and then kneaded (by machine) to a fairly stiff paste. Balls of this paste are left in a heap, and after ageing they are again worked through the kneading machine. A mass so prepared had the grading:—

Mesh of Sieve	8	10	14	18	20	40	60	80	100
Percentage	0·77	5·86	14·04	6·51	27·26	11·29	5·32	3·56	25·38

A sample from the clay press contained 78·96 clay and grog (calculated as calcined substance), 5·16 combined water, and 15·88 per cent. moisture. The shaping of this mixture was done by expression, the retorts being afterwards dried slowly for about 60 to 70 days at about 35° C. The retorts lose about 15 per cent. in drying. The linear contraction was found to be 3·5 per cent., the porosity 21·8 per cent. of the volume, and the density 2·0 per cent. Fiske[3] mentions drying for 2 to 3 weeks at ordinary temperatures, and then gradually raising the temperature to a maximum of 120—125° F., the whole drying period being 4 months. Fiske states that while St. Louis clay is used as bond clay, calcined flint clay has been found better for grog than old bats, etc. Promising trials have also been made with broken pottery saggars. The grog is screened through 6-mesh and the bond clay through 8-mesh.

Fiske[3] states that a good commercial sizing is 25 per cent. 10—16 mesh, 25 per cent. 16—30 mesh, and 50 per cent. through 30 mesh. For zinc retorts and muffles the mixture used consists of 145 St. Louis clay, 150 calcined flint clay, 19 lb. pulverized coke, mixed with 10 to 11 per cent. water. Fiske further states

that rotting may be carried too far, for the tensile strength increases up to a maximum and then steadily decreases.

E. M. Johnson[9] gives about 70 parts burned clay to 60 of raw clay. He states that many troubles may be traced to improper weathering.

In Belgium and Westphalia the retorts are often glazed externally in order to render their sides impervious to zinc vapour. In many Belgian works, and in Spain, much quartz or sand is added to highly siliceous clay, so that the retorts consist chiefly of silica, which stands fire well, is a good conductor of heat, and enables thinner vessels to be made, but it is certainly less resistant than alumina to fluxes, though not so much corroded by siliceous ores. These retorts are also often glazed.

The condensers are made of less refractory materials than the distillation vessels. In many places they are made of equal parts of raw and burned clay, or of ordinary clay mixed with ground retort fragments and coke or coal ash. Fiske[3] gives equal weights of St. Louis clay and grog, mixed with 14—15 per cent. water.

The losses of zinc, under the most favourable circumstances with rich ores, amount to 10 per cent. of the contents of the ore, and in the case of poorer ores to 30 per cent. These losses are due to zinc remaining in the retort residues, to zinc vapours remaining in the retorts at the end of the distillation and subsequently burning on the admission of air when the residues are removed, to imperfect condensation of zinc vapours, to the escape of zinc vapours from the vessels, and to the retention of zinc as an aluminate in the walls of the retorts.

The refractory quality of the material used for making the retorts and muffles has undergone improvement, and other modern improvements consist in the employment of hydraulic pressure to produce vessels with dense walls, in the improvement of the arrangements for condensing and collecting the zinc, and in keeping the interior of the zinc works free from fumes.

The charges are prepared by mixing the ores according to their zinc contents with 40 to 60 per cent. of their weight of lean coals, or small coke, or a mixture of coal and coke. The mixture is slightly moistened to prevent its expulsion from the retorts by the gases given off at the commencement of distillation. Some mix the charge with tar, and press it into blocks before putting it in the retorts. The time of distillation is usually between 12 and 24 hours. With the horizontal retort furnace the campaign takes about 24 hours, ½ to 1 hour for renewal of defective retorts, 2 hours for discharging the residue of the previous distillation, 2 or 3 hours for the introduction

of the new charge (including fixing of adapters and luting, etc.), leaving perhaps not more than 18 hours for the distillation.[1] In vertical retorts these operations might be greatly accelerated, giving about 22 hours for the distillation. Against the argument that the zinc fumes would not penetrate through a dense charge in a vertical retort, and that the slag formed in the hottest zone would tend to retain the zinc, it is suggested that difficulties might be overcome by intimately mixing the roasted ore, when fine, with the reducing material, and making briquettes.

The greatest loss of zinc arises from the retention of zinc by the distillation residues, and next to that comes loss by volatilization. The walls of new retorts absorb zinc at first, forming zinc aluminate (artificial zinc spinel), which gives the well-known blue colour. The average zinc contents of old retorts is 6 per cent, but may rise to as much as 21 per cent., as at the Bethlehem Zinc Works, Pennsylvania; in seven samples of broken retorts from Upper Silesia the average amount of metallic zinc was 12·87 per cent.[17] The addition of coke to the retort material, and the employment of heavy pressure in making the retorts, has resulted in greatly reducing the absorption of zinc. During the distillation the pressure of vapour in the retorts causes zinc vapour (with other vapours) to pass through porous retorts and escape with the products of combustion in the furnace. If the pressure of vapour in the retorts be low, and that of the furnace gases higher, the furnace gases and air pass through the walls of porous retorts, and the oxygen and carbon dioxide present oxidize the zinc vapours. In order to avoid this risk the retorts have been glazed, but this has been shown to be less effective than making retorts under hydraulic pressure. The average life of retorts in the furnace, and also of small and large muffles, is about 40 days, and each day 2 to 3 per cent. of the retorts in use are broken.[17] It might be expected that the retorts and small muffles made under pressure would be more durable than the hand-made large muffles; but the latter have much better support, whereas the retorts and small muffles are only supported at their two ends, and have to resist a very intense heat. The average life of hand-made retorts and small muffles was only 25 days.

The condensation of zinc vapours is only complete between the narrow temperature limits of 415° and 550° C. Below 415° C. the zinc passes from vapour direct to solid and forms a fine dust. Above 550° C. the zinc vapours escape without being condensed.

The prevailing temperature in the zinc furnace when defective retorts are replaced by new ones fluctuates between

1,200° and 1,350° C.[14] The retorts leave the furnace after their first burning with a temperature of 750° to 780° C., and, after cooling somewhat during transport, they endure a sudden rise of about 600° C. This causes cracking on the outside surface. The contraction of the clay substance and the activities of the fluxing material vary with the temperature, which is greater at the hinder part of the retort than in front, and greater in the outer parts than towards the interior. After 24 hours' heating in the furnace the outer surface of the retort is covered with a thin layer of glaze, which also passes into the surface cracks, and appears brownish-yellow; this is due to the action of dust. Small cavities appear on the outer surface, and also in the interior of the fired body, originating from iron oxide (or pyrites, gypsum, calcspar, etc.), which after forming fusible silicates have been gradually absorbed. On the outer surface this action is nearly completed within 24 hours, but in the interior are cavities wholly or partly filled with iron oxide. Mühlhæuser[14] found the porosity at this stage to be 24·5 per cent. by volume, as against 28·0 per cent. porosity after the preliminary burning. The strongly heated clay of the retort is no longer brittle, but more or less elastic.

The fine dust from the coal (consisting of silica, clay substance, iron oxide or pyrites, lime, magnesia, and alkalies), continues to attack the clay substance of the porous vessels, forming a gradually thickening glaze. The zinc vapours in the meantime will change the clay substance into zinc aluminate (zinc spinel), the silica—both that from the clay substance and quartz grains in the clay—being partly transformed into tridymite. The zinc spinel is formed particularly during the first time of using the vessels, while zinc vapours and combustion gases can diffuse readily through the retort before the coating of glaze is formed. By means of analyses, Mühlhæuser ascertained that nearly all the zinc was taken up during the first eight days of use, the increase between eight days and 135 days in use being only from 13·50 to 15·15 per cent. of zinc.[14] Thus, after being in use a few days, the retorts do not consist of fireclay, but mostly of zinc spinel and tridymite. The reduction temperature for zinc oxide was found to be about 1,000° C. (60° above the boiling point of zinc), and zinc spinel is believed to be formed at temperatures above 1,000° C. Within a period of 24 hours the temperature in the zinc furnace—in the ashes close to the retorts—was found to range between 1,322° and 1,076° C., and remaining for only about seven hours below 1,180°. The temperature in the retorts during the same period ranged between 1,188° and 781° C., and was below 1,050° only for eight or nine hours. The difference between the outside and

inside temperatures ranged from 286° C. in the very early stages of distillation to 88° near the end, but at only three of the half-hourly intervals at which readings were taken was the difference less than 110° C.[14]

The very fluid slag from the ashes of the ingredients penetrates parts of the retort, particularly on the underside, producing a mass with little porosity. To prevent this as far as practicable, the mixture should be arranged to have comparatively little silica with much lime, or lime and magnesia, or much alumina, or in the opposite case much silica with only small quantities of bases, in the ashes.

In considering the *causes of the destruction of retorts*, we may note that a white hot cylindrical retort from a zinc furnace would only with difficulty be crushed by a blow from a heavy hammer according to Mühlhæuser,[11] who made a close study of the subject. As the temperature falls the strength decreases and the tubes generally crack badly during cooling, the worst cracks being longitudinal and transverse. The cooled vessels are more or less coated with a deep black glaze, sometimes with a shade of green or brown according to the nature of the combustion gases. The fired body is greyish-blue, dark-blue, greyish-green, greyish-yellow, or greenish-yellow. Besides the longitudinal and transverse cracks, broken retorts show a branched network of external surface cracks, which were produced at the time the retorts were set in the furnace; these cracks are covered with glaze and apparently healed up, but all the cracks are found to be connected with passages leading to the interior of the fired body, and the clay mass on each side of a crack is found to be strongly though irregularly corroded. Penetration, however, was never found to extend more than a few millimetres in depth. Many similar net-like cracks, with the same internal connections, occur on the inner surfaces of the tubes. On the under side of the retorts the inner surface cracks are covered with slag, but on the upper side they are not distinctly visible. The cause of these cracks was not determined. They may have been formed when the retorts were set in the furnace, but possibly they were produced when the moist cold charge was thrown into the hot tubes. If these cracks run deeply they soon become filled with easily fluid double silicates, which combine with the clay mass to form a dense vitrified body resembling stoneware, with a different coefficient of expansion from that of the neighbouring porous mass, so that fracture easily occurs at such junctions. The same appearance is noticeable about the mouth of a retort, owing to similar differences in adjacent parts. Different parts of a retort (from

above, below, and round bottom) were found to have specific gravities 2·48, 2·75, and 2·93 respectively.

Mouth cracks, by which the mouth of a retort is wholly or partly split through, arise at all times. The mouth of the retort always receives less heat than the rest, and, when setting in, the mouth is cooled locally by the application of moist clay for luting, while the main body of the retort is strongly heated. The fired body is a bad conductor of heat, so that the mouth is always distinctly cooler than the parts lying deeper in the furnace, and the resulting tensions may produce cracks at any time.

Cracks also result frequently from mechanical influences, as in violently breaking out the receiver, and in scraping the zinc roll forming in the retort mouth. The mouth cracks are often filled with white or yellowish sublimates of zinc oxide, which recall the deposits of zinc oxide found in blast furnaces. Thus J. E. Johnson[11] mentions the occurrence of yellowish-white hollow thin-walled columns (2 to 6 inches or more in length), of zinc oxide looking like little stalagmites standing up all over the bosh wall, which were found to be derived from the zinc oxide in the brickwork of the bosh.

Holes through the walls appear to arise only when bits of iron get into the mass, or when iron present in the ore has the opportunity to collect, and corrosion follows.[14] Within the fired mass may often be noticed small cavities of the size of a millet grain, or even as large as a pea, arising from the burning out of foreign bodies; these do not adversely affect the durability of the vessels.

Frænkel[4] considers that a certain amount of zinc is lost in the muffle by the formation of a volatile compound of zinc sulphide and carbon which reacts with silica, reducing it and giving a compound approximating in composition to ZnSSi. This compound, which was isolated as a sublimate on an experimental scale, is a hard, brittle and apparently homogeneous substance. Similar observations have been made by Lepiarczyk.[12]

During use in a zinc furnace, when a retort becomes more or less fired up, contracts, and adapts itself to the temperature conditions, it becomes saturated with zinc oxide, and glazed over, and finally becomes changed, largely by penetration of fluxing material into the fired body. A zinc retort is thus a porous vessel, more or less damaged by various cracks, mainly consisting of clay substance, zinc spinel, and quartz or tridymite, with modifications in parts through local vitrification. In the zinc furnace the vessel can resist powerful mechanical influences, because the fired body, though brittle when cold, has great

tenacity in the white hot state. Next to the durability of the vessel the most important factor in the valuation of a retort is the resistance which the fired body opposes to the passage of vapours through the wall.

The degree of impermeability to zinc vapours depends largely on the kind and number of external and internal surface cracks, and on the density and viscosity of the glaze.

Mühlhæuser[14] carefully determined separately the losses in zinc by absorption, volatilization, etc., in the case of a few retorts newly set in, for a week, and the total losses on the successive days amounted to 32·35, 29·89, 20·97, 16·07, 16·97, 13·41, and 8·30 per cent. respectively.

Mühlhæuser[15] also states that reddish-brown bricks made of St. Louis clay—which in the burned state contained 56·03 silica, 39·26 alumina, and about 3 per cent. of ferric oxide, and only small amounts of lime, magnesia, and alkalies—answer very well for the median wall of the zinc furnace. He found the temperature at a place about 10 cms. from this median wall, by two-hourly measurements during a distillation period, to range between 990° and 1,315° C., only two of the temperature readings falling below 1,122° C. The heat in a zinc furnace fluctuates day by day, but always remains tolerably even within these limits. The volume of a brick which had been in the median wall for 75 months was found to have diminished from 51·1 to 45·3 c.c. per 100 grms. By burning the bricks to about 100° C. higher than the maximum temperature in the zinc furnace it is concluded that bricks can be made which would answer all demands.

Schulze and Stelzner,[18] who investigated zinc distillation vessels many years earlier, and from a different standpoint, reported that the yellowish-white colour of Silesian zinc muffles during use changed to blue—pale sky-blue, lavender blue, and blue-black—and that they acquired a coarse columnar structure, so that when broken up with a hammer they split very easily at right angles to their surface but with more difficulty in any other direction.

The blue coloration commences within the first 14 days of using the muffles, but gradually becomes more intense, and a very dark colour is regarded as evidence of good quality and durability. Usually the blue colour begins to appear most strongly in the side walls of the muffles, above the level of the charge (and therefore where vapours are most abundant). Below this level the blue colour is soon lost, and above it becomes weaker, though it extends through the arched portion of the muffle. Irregularities in distribution of the blue colour often arise from unequal porosity and the course taken by the

shrinkage cracks. The blue coloration was developed with all kinds of furnaces, and in muffles made from Silesian, Polish, and Galician clays, and it was also known to occur in Spanish zinc works.

The yellowish-white unchanged parts of muffles examined under the microscope revealed only a quite or nearly opaque, white, dense mass with small cavities, and occasionally a transparent quartz granule. In parts scarcely perceptibly changed to the naked eye, a very fine granulation was developed, and a transparent isotropic substance was formed, filling up small cracks and cavities; in the midst of this glass were to be seen aggregations of small colourless microlites, groups of transparent prismatic needles, and transparent octahedra. The extent of the transformation increased as the blue colour appeared, and eventually in the very dark blue material the original muffle mass was found to be represented only by a few small grog fragments and quartz granules, the greater part of it being replaced by a structure partly glassy and partly crystalline, traversed by bubbles and cracks. This structure consisted of a varying amount of glass, with numerous granules and little octohedra of spinel, besides crystals and crystal groups of tridymite. In some cases prismatic needles of zinc silicate also occurred (see below). The glass was sometimes colourless, sometimes pale yellowish, to violet brown and was very probably a silicate of zinc oxide and ferrous oxide, with perhaps small quantities of alkaline earths and alkalies. This glass is usually homogeneous, with occasional groups of microlites or crowds of minute dark granules, which may be recorded as devitrification products. In rare cases the glass becomes divided into a somewhat darker marginal zone and a lighter central zone, the latter being quite structureless and isotropic, but the former giving indications (between crossed nicols) of a radially fibrous structure, evidently representing a stage of transformation of the amorphous zinc-containing silicate into the crystalline form. Their further development may have been interrupted by rapid cooling of the muffle.

In sections of a dark blue muffle the microscope shows mostly a microcrystalline aggregate of blue transparent roundish granules and transparent minute crystals, with little glass. Where the glass is more abundant the dense crowd of crystalline elements relaxes, the blue granules assume regular forms and finally develop into elegant little octahedra. The octahedra occur singly and in groups, and correspond in composition and physical properties to zinc spinel.

Quite gradual transition stages are to be found between the minute colourless granules and the larger blue octahedra,

and they have all the same qualitative composition, and are equally resistant to hydrofluoric acid. The larger grains and crystals of spinel, which are found in the parts of the muffle which have undergone the greatest change, are usually coloured blue, and nothing else has this colour. Hence the blue coloration of the muffles is based on the formation of blue zinc spinel as was first shown by Degenhardt in America.[2]

The coloration was shown *not* to be due to ferrous oxide, sulphur, hydrocarbons, or titanium. It becomes a light grey after strong ignition with access of air, but remains unchanged in a stream of carbon dioxide or hydrogen. The results of analysis agreed with the composition of zinc spinel, $ZnO.Al_2O_3$, but with about 1 per cent. of the zinc replaced by ferrous oxide. The specific gravity was found to be 4·45 to 4·52, as compared with 4·58 for Ebelmen's artificial zinc spinel, and 4·52 to 4·56 for the mineral gahnite (native zinc spinel) from Brazil.

This zinc spinel does not melt before the blowpipe, and is not attacked by acids, except boiling sulphuric acid.

Quartz granules and little fragments of grog are so resistant that some are found even in the deep blue parts of muffles. In thin sections, little grog fragments show under the microscope a cloudy opaque core in which are scattered irregularly somewhat translucent spots, while towards the margin minute colourless granules and small octahedra may be visible. This is evidently the first stage in the transformation of the grog. The small grog particles next develop a peripheral zone, which soon becomes differentiated into two concentric portions. The inner of these two marginal zones consists of a transparent, structureless, isotropic substance and in this ground-mass appear microlitic structure and minute transparent octahedra of spinel, singly or in groups. These minute crystals increase in number and become blue, and the marginal zones now consist essentially of densely crowded violet blue grains and octahedra of spinel, among which are to be found single small crystals of tridymite, while the colourless mass of the inner marginal zone has almost entirely disappeared. Wreath-like aggregations of spinels also occur on the walls of cavities and tubular channels in the grog particles, and as there is no evidence of glassy material there the spinel seems to have been produced by the action of zinc vapours on the hot blistered and cracked grog.

When the muffles are removed from the furnace the silicate, rich in zinc, solidifies to a glass, filling all the cavities.

Tridymite.—Among the blue grains and crystals of spinel constituting the main portion of the blue parts of muffles are

crystals of tridymite with rectangular or lath-shaped sections, which show double refraction. Sometimes groups of minute scaly crystals of tridymite are found, resembling those of certain trachytes. In the violet and brown glasses are to be found colourless six-sided plates with rectilineal or somewhat bowed margins, and fan-shaped twins, etc. The presence of tridymite was confirmed by means of chemical tests. Almost the whole of the alumina was found to be converted into spinel, and the silica present was mostly free. One determination gave 62·82 silica and 32·58 spinel, leaving not more than 4·6 per cent. of bases not combined as spinel. This 4·6 per cent. consisted chiefly of alumina, iron oxide and zinc oxide, with less than 1 per cent. of alkalies and alkaline earths together. Even assuming that 4·6 per cent. of bases soluble in hydrofluoric acid were combined to form a complex silicate containing 70 per cent. of silica, there would still be 52 per cent. of tridymite, but probably more than this would be present. Most of this tridymite must have been liberated by the direct or indirect action of zinc vapours on the clay substance of the muffles. A small portion of the tridymite may possibly have been derived by transformation of quartz granules present in the clay. Those quartz granules have certainly suffered a partial transformation, because they are usually divided into a clear unaltered core with a cloudy sheath. In view of the observation of G. Rose[16] that powdered rock crystal is transformed by strong heating into tridymite, the cause of the change is evident. Hautefeuille[5] also noted the conversion of quartz into tridymite. These early observations possess at least a passing interest in view of the industrial importance of such transformation in connection with silica bricks.

Willemite-like zinc silicate.—In the partly glassy and partly crystalline ground-mass of blue muffles are sometimes found columnar crystals, single or clustered. Occasionally finer needles and rod-shaped microlites occur in the glassy portions. Cross sections are often met with having regular or warped hexagonal outline. Similar crystals occur, in slag incrustations formed on the inner surfaces of muffles, by the charge and the muffle mass melting together, especially during the extraction of the charge.

Schulze and Stelzner[18] found willemite associated with zinc spinel, while Hutchings[6] observed perfect rhombohedral crystals of the same mineral in the cavities of firebrick supports of retorts. These were apparently formed by oxidation of zinc and combination of the oxide with silica. Similar crystals, associated with fayalite (ferrous silicate) have been found in cavities in slag balls from the smelting of lead dross.[19]

On the outer surface of a muffle zinc oxide sometimes forms an incrustation, and small yellow brown flakes of iron oxide occur within the muffle mass.

A zinc plagioclase was met with on one occasion in slag incrustations from the inner surface of a muffle. It was found to be composed essentially of silica, zinc oxide, ferrous oxide, and alumina. Cross sections of this mineral were rectangular, and between crossed nicols they showed well the parallel striations of twinned plagioclase crystals.

Possibility of improving zinc refractories.—It would appear that porous vessels produced from a mixture of clay and grog, exposed for 5 or 6 weeks to a high temperature (mostly approaching 1,300° C.), and at the same time subjected to the action of zinc vapour, water vapour, carbon dioxide, carbon monoxide, and methane or other hydrocarbons, though the mass as a whole remains rigid and at most is softened locally, become transformed more or less completely into crystalline mixture of zinc spinel and tridymite. A small quantity of a glassy flux (essentially zinc silicate) is also formed, and dissolves either portions of the products mentioned, or their necessary elements, to deposit them as crystals on cooling. The grog particles, which are more resistant than the clay, become transformed, at least on their outer margins and on the walls of pores and channels traversed by vapours, into zinc spinel tridymite and zinc silicate (willemite). The quartz granules suffer on their surface molecular re-arrangement into tridymite. By the melting of the charge along with the clay mass zinc silicate is produced as vesicular crystalline incrustations on the inner surface of muffles, and also in the substance of the muffles. Occasionally other products appear.

Both zinc spinel and tridymite have high melting points. The latter has recently been accurately determined by Ferguson and Merwin[2] to be 1,670° ± 10° C., and that of cristobalite, the other high temperature form of silica, was found to be 1,710° ± 10° C. Stein gives the melting point of willemite as 1,429° C. Thus there is no appreciable loss of refractoriness in zinc muffles as a result of the transformations, the most important cause of which is the zinc vapour. (Whether water vapour be essential or not, the actual amount of the water vapour is of no consequence).

Steger, who carried out investigations similar to those of Stelzner and Schulze, has proposed the use of magnesia (calcined magnesite) instead of clay for making zinc muffles or retorts, and recommended the building of large fixed muffles from magnesia tiles. Magnesia is stated to conduct heat nearly three times as well as clay, to be impenetrable by zinc vapour,

to be much stronger than clay, besides resisting higher temperatures. He claims as advantages the great durability of magnesia vessels, small loss of zinc, possibility of charging with very finely divided ore, absence of necessity for replacing retorts, greater durability and larger dimensions of the adapters, more rapid charging and drawing, and easier and more healthy working. Steger's furnace, patented under the name of Francisci (D.R.P. 76,285, British Pat. 23,979) has been tried in Silesia. The magnesia bricks first used proved very sensitive to temperature changes, and the results of later trials have not come up to expectation.

Landsberg[17] proposed to make retorts coated inside with a mixture of graphite and clay, and coated outside with fireclay, as protection against the charge and furnace gases respectively.

As the worst effects of porosity are due to the formation of superficial cracks, the idea of using protective coatings seems capable of further application. If the outer surface were composed of some material which would not crack in the furnace it should go a long way towards meeting the difficulty. Two materials suggest themselves in this connection, fused bauxite prepared by the Lecesne process, and zirconia. The fused bauxite might also be considered as a possible addition to the clay mixture. The obvious objection to its use is the tendency to forming zinc spinel, but this might prove to be the lesser of two evils if the formation of surface cracks could be prevented. As regards zirconia, its low conductivity for heat would be a drawback for this purpose, but a very thin layer might answer, especially if placed over a previous layer of zirconia mixed with prepared retort mass; it seems again to be a choice between two evils. The introduction of a proportion of a silicon carbide (such as carborundum) into the mixture used for making retorts, with a view to increasing the conductivity for heat, might be worth serious consideration.

Another point which may bear consideration is the question of producing the retorts by casting. No doubt this method has been tried, but my experience in more than one factory has proved that unusual methods, though tried in perfect good faith, often exhaust the patience of the experimenters long before the possibilities of the methods themselves are exhausted. The question of porosity of course makes the suggestion of casting seem unpromising, but density and porosity depend largely on proper grading of the particles. One advantage of casting would be the readiness with which special coats could be applied, even a coating of glaze if desired.

The foregoing suggestions are offered with some diffidence, but any healthy discussion which they may provoke can hardly fail to be helpful.

In conclusion, I desire to acknowledge my obligations to Dr. J. W. Mellor for valuable suggestions, and to Dr. A. Scott for important references.

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DISCUSSION.

Mr. H. M. RIDGE:—I would like to thank Mr. Audley for the paper he has presented to us. Spelter production is not only of importance to the actual manufacturer and user, it is one of the coming industries of the country. We have suffered during the war very considerably in consequence of shortage of spelter and high grade zinc. Unfortunately our production in 1913 was 56,000 tons, and our consumption 226,000 tons. Our production was about a quarter of our requirements, and the balance was imported from the Continent. The British Empire is not deficient in zinc ore. A large quantity was sent from British colonies and from this country to foreign countries for smelting. We ought to have been able to smelt the ore here and make our own spelter. Some extensions have been built, but, although the press has given considerable attention to this subject, I regret the results have not been anything like what one would have hoped or expected. I cannot see that at the termination of war we shall be able to produce even 50 per cent. of our pre-war requirements. The position is even more serious than that, because the post-war demand will be very large, and if we are to compete with finished products in the world's markets we shall be obliged to again import spelter. In no important branch of manufacture have we lagged behind more than in the spelter industry. The Swansea district is, of course, pre-eminent in the British Isles for spelter manufacture, and everything that can be done to increase its capacity is of national importance.

Before the war we not only allowed over 400,000 tons of our ores to go annually to the Continent, but at the same time we did not develop our British resources of fireclay materials. A considerable proportion of the clays used for making zinc retorts were imported from abroad. The clays used should be divided into two distinct classes, high silica and high alumina. The former we obtained from Belgium, and the latter from Germany, Austria and Scandinavia. It is interesting that both kinds have been used satisfactorily for treating ores rich in lead, for instance the concentrates formerly produced at Broken Hill.

The subject of this paper is of primary importance, and I regret it is impossible to cover the field in its discussion. I will confine myself to a few points in the paper. About the centre of page 45 the author refers to the muffle used in Upper Silesia. The analyses of these retorts show 40 per cent. to 43 per cent. alumina; considerable quantities of the clays from which the muffles were made were brought here before the war.

I think from the point of view of The Ceramic Society it would be desirable to extend this paper, and, if the author could do so, I would suggest adding as many analyses as possible to it. The large muffles are made entirely by machinery. The presses were formerly imported from Germany, but during the war I have taken up the manufacture here, and the results are perfectly satisfactory.

Then on page 53, regarding the action of iron on the retort mass, metallic iron does not act noticeably on the body of the retort, but, if the ore is imperfectly roasted, iron sulphide is present and this rapidly attacks the retort. Taking high alumina materials with well made retorts, I have not found attack from lead even when treating roasted ore with 15 to 18 per cent. Pb, and my experience with roasted ore carrying 22 to 25 per cent. iron has been similar, provided the ore was properly roasted and low in sulphur.

The author gives on page 54 a statement of the zinc absorption, and quotes as an average of seven samples 12·87 per cent. zinc. I have found that some high alumina retorts showed a maximum of under 7 per cent. zinc, and the portions containing that were only 20 per cent. of the weight of the whole retort, while the balance was practically free from zinc after the retort had been 40 days in the furnace. This shows a marked discrepancy compared with the author's figures. He gives the average life as about 40 days. I think our local friends will agree that 40 days under present conditions is rather high, and 25 days would be nearer the mark; 42 days was an average I succeeded in reaching when we had the very best foreign materials available. I hope British material will eventually produce retorts which will stand similarly well.

The author mentions the question of magnesite for making retorts. It has been tried on the Continent and given up. It is, however, most efficient for the lining of the furnace. One of the Austrian Government works is an example. Twelve furnaces lined entirely with magnesite bricks after 14 years were standing admirably. I was particularly struck with the condition of the top arch, which was as good as new in each furnace; the gas ports showed little erosion, and while the regenerators were being cleaned the lumps at the gas ports were taken out and reversed.

The subject is such an extremely important one from a national point of view that I trust there will be considerable discussion on this paper.

I tried some years before the war to use entirely British materials for the structure of a furnace. I was faced with

difficulties, mainly of shrinkage of the firebrick in use. I have had material from some firebrick makers in the country which has shown, after only three to four months, a shrinkage of 1 in. in 20 in. I ought to say that it is an exceptional case and is the largest shrinkage I have been able to determine. There is no doubt that using proper materials made in British works satisfactory results can be obtained. I have built furnaces which have stood satisfactorily and have had a furnace campaign of over two years. This, of course, was not the life of the furnace, which can be put at 15 to 20 years. The maker for the essential refractory parts requires watching, and his bricks will have to be well and better burned than is the usual practice. His raw materials have to be suitable and well selected.

Regarding the question of British clays for making retorts, that is a question on which I hope, by the time of the next meeting of this Society, you will be able to report results proving that the fireclays will stand comparison with those formerly obtained from Germany and Belgium.

Mr. D. MARMION:—I did not intend to make any remarks because I have not had a chance to go into the paper. On the other hand I was disappointed that Mr. Audley confined his paper to the retorts, because I may say that we have had less trouble with retorts made from British material than we have had with bricks. We have had practically no trouble with our retorts, but we had much trouble with bricks.

The chief trouble has been from excessive shrinkage, and the only way we have been able to overcome that shrinkage has been to get British manufacturers to make a composite brick containing a high percentage of silica. When discussing bricks one must always bear in mind the temperatures which they are to stand, and the temperatures quoted by Mr. Audley are very much below those which prevail in modern zinc smelting furnaces.

When subjected to these high temperatures—about 1,600° C.—the shrinkage of bricks manufactured from ordinary fireclay is absolutely too great to enable their being used with any degree of safety.

In my opinion, as we know our clays at the present time, I do not see much prospect of manufacturing bricks from a straight clay to stand these temperatures, and as far as I can see the future lies in perfecting the manufacture of composite bricks.

Of course, one knows such bricks cannot be manufactured at the same price as bricks from a straight clay; but it is not,

however, necessary to use these high quality bricks in all parts of the furnace, they need only be used in those parts which are subjected to the greatest temperature.

I understand that some of the gentlemen present to-day are coming out to the Swansea Vale Works this afternoon, where I shall be very pleased to explain the construction of our furnaces and point out where we find it is advisable to use bricks of different quality.

I would like to make the suggestion, following the remarks your President made last night, that if we are to make any great improvement in the zinc industry in this country, it is absolutely necessary that refractory manufacturers and smelters should divulge the result of experimental work of mutual interest to one another to prevent overlapping and to ensure that the results of such experiments are confirmed in actual practice.

Mr. G. V. EVERS:—From the point of view of the brick-maker may I be allowed to say that sometimes trouble is due to the design of the furnace as well as the material used. For instance Dr. Mellor, in a recent investigation, has pointed out that the liability of the brick to soften is very enormously increased by the amount of surface which is exposed to the heat, and he shows how on the surface there is a much greater temperature than say 1 in. or 3 in. below the surface. In furnaces of various sorts and kinds where it is necessary to have heat on both sides of walls it is obvious that the structure is in very greatly increased danger if such walls are pierced by apertures purporting to allow freer passage of gases. It might be possible at times to avoid this, and to bring in the flow of gas in other ways.

With regard to the life of the retorts, I think Mr. Ridge said that 40 to 42 days' life was obtained with the best foreign material. I venture to say that the life is largely reduced on retorts in modern practice whether foreign materials are used or not. The life of the retorts to-day is, I am pleased to say, as good with English clays as if foreign materials were used. We are able to get 42 days or more, and where the life is less it is due to the greatly increased duty put upon those retorts rather than the material used.

Mr. L. SOUTHWOOD JONES:—I am afraid it is rather difficult for me to pass an opinion upon such a very technical subject, except that I have supplied a quantity of firebricks to manufacturers. I think a great deal of the question of bricks sent to spelter works is that they must be hard-burned. I have

not had the pleasure of supplying the Swansea Vale Co., and their conditions may be different to other spelter manufacturers. I have certainly had one or two complaints over a long period of time, but they have generally been due to soft bricks. I can only repeat that, speaking as a local manufacturer, I think that hard-burning of firebricks to prevent that shrinkage is a very vital thing, and I think it is possible that some of the firebrick works do not understand that.

Mr. H. M. RIDGE:—A gentleman asked me a question and, in reply, I would quote a case from practical experience. I built two furnaces here which failed for the same reason, shrinkage of firebricks; they did not stand five months. I modified the quality of the bricks and the design of the furnaces, with the result that the furnaces have stood well and proved more economical in fuel consumption than the older design. No firebrick maker seems to want to add more than 15 per cent. of grog, the maximum is about 25 per cent. How does that compare with German practice? The Germans did not use 15 per cent. or 25 per cent. of grog. They used as much as they could put in their bricks, frequently 50 per cent. and 60 per cent., and sometimes more. I think that is really the important factor, and the point should also be brought out that the Germans burned their grog at a high temperature and absolutely dead, so as to get rid of the last shrinkage they were able to dispose of. Frequently they burnt the grog in lumps twice, only removing the finer and then refilling the kiln. That means the bricks did not shrink.

On the question of retort manufacture the Continental practice has also been to add more grog than we usually do here. I have in this country used 66 per cent. grog and 10 per cent. of non-plastic clay with only 24 per cent. of highly plastic clay. These retorts stood extremely well in the furnace and absorbed only a small amount of zinc. They were dense and no zinc vapour escaped by leakage through the retort walls.

Mr. J. A. AUDLEY:—While feeling gratified that the value of the paper will be materially increased by the discussion which has taken place, I am sorry that some points of practical importance have not been alluded to by any of the speakers.

Mr. Ridge will be interested to learn that a number of analyses were actually got together, but it was found impracticable to include them in the preprint. They will probably be included when the paper appears in the TRANSACTIONS, and references to sources of information will be added. The statement concerning the action of iron on the retort body is based

on the experience of Mühlhæuser in America. It is satisfactory to find the proportion of zinc so much reduced in retorts with high alumina. This looks very like a justification (by anticipation) of my suggested addition of bauxite to the clay mixture for retorts.

The average life of 40 days for retorts was not intended to apply to present conditions, and the same remark would apply to other statements, though possibly this might have been made clearer.

Mr. Ridge has, in my opinion, touched the spot when he remarks that refractory bricks have to be better burned than is the usual practice, and that the raw materials should be well selected for their purpose. Mr. Southwood Jones is to be congratulated as a manufacturer on realizing the vital points. There is nothing wrong with British raw materials if properly selected, but it is unreasonable to expect the same materials to answer equally well for very different requirements, especially if the volume changes have not been completed (or nearly so) by burning. This is the more necessary the higher the working temperature. The same considerations apply to all the usual refractory materials or mixtures of them, and in the particular case of refractory bricks made of fireclay the proportion and grading of the added grog are essential factors. As Mr. Evers reminds us, it is only the parts on or close to the surface which have to withstand the very high temperatures.

V.—Magnesite as Raw Material.

By Thomas Crook.

Review.

THE utility of crystalline magnesia for refractory purposes is not a recent discovery. Advantage was taken of it in scientific laboratories long before its economic importance was realized in the smelting industry, and the use of magnesia on a large scale in metallurgical practice during recent years must be attributed to a growing taste for technical efficiency in furnace operations, rather than to any new knowledge that has been acquired concerning its refractory properties. This growing taste has been fostered by the production of sinter and bricks of good quality at a comparatively cheap rate, largely owing to the enterprise of a German firm, which led the way in the exploitation of the Styrian and other deposits of Austria-Hungary.

It is said that when Spæter & Co. of Cologne started mining enterprise in the Veitsch district of Styria, about 1880, they went there for the purpose of mining spathic manganese ore. Spathic iron ore had long been mined in this district, but the quality had steadily deteriorated as compared with other Styrian mines, and its exploitation had ceased to yield much profit. It was during the development of their manganese property that the Cologne firm realized the possibilities of refractory-magnesia production from the large deposit at Veitsch.

The exploitation of the Veitsch and other magnesite deposits of Austria-Hungary, and the growth of the Veitscher Magnesitaktiengesellschaft as a monopoly, is merely an instance of what can be done by a sound business organization in which full use is made of the scientific and technical worker. The German company did not discover either the refractory properties of magnesia or the way to make good magnesia bricks. They did, however, diligently enough, strive to produce a good refractory magnesia from material which, at the outset, could hardly be considered of very promising quality in comparison with Grecian magnesite; and they succeeded so well that, at the outbreak of war in 1914, Austria-Hungary had been for

some years producing almost the whole of the world's metallurgical requirements of refractory magnesia.

It is therefore well worthy of note that a great deal of work had been done on the manufacture of magnesia bricks from magnesite of the Grecian and Salem (India) type long before the Germans began to supply the world's needs from the breunnerite deposits of Austria-Hungary. It is still more noteworthy from the ceramic point of view that the use of magnesite as a refractory appears to have grown as an offshoot of pottery manufacture, though the first employment of the mineral for the latter purpose appears to have been associated with a mistake as regards its identity.

The siliceous magnesite of Baudissero in the Piedmont is reported to have been used quite successfully in porcelain manufacture, at and previous to the beginning of the 19th century. This particular magnesite was at that time regarded as a high-class china clay (terra da porcellana) and was not known to contain any magnesia. Giobert analysed it and proved it to be a siliceous magnesite containing no alumina. He mixed the magnesite with sufficient clay to secure a pasty consistency and made it into refractory crucibles.[1] In the earlier half of the 19th century the French workers used magnesia crucibles for the fusion of platinum, and Regnault states that several of these magnesia crucibles were given to him by Thilorier and used during trials in the kilns of Sèvres.

In 1866 M. H. Caron[2] called attention to the value of magnesite as a source of refractory magnesia. At that time crude magnesite cost 250 francs per metric ton and was too expensive to use except for laboratory purposes. The Siemens-Martin process and the use of magnesium oxychloride cement were introduced about that date, or very shortly afterwards. These doubtless created a larger demand and cheapened the rate at which the mineral could be obtained. When, two years later, Caron gave his account of a method of manufacturing magnesia bricks[3] and emphasized their utility in the Siemens-Martin furnace, he stated that magnesite could then be obtained at the much cheaper rate of 70 francs per metric ton delivered at Marseilles and 100 francs delivered at Dunkirk.

One notes, therefore, as a matter of considerable interest, that the raw magnesite used in those early days of magnesia-brick manufacture was of the compact (Grecian) type. Caron used Eubœan magnesite in making his bricks. Moreover, the compact magnesite of Frankenstein was used by Germans in

1 *Journal des Mines*, **20**, 118, 291, 1806.

2 *Compt. rend.*, **62**, 299, 1866.

3 *Compt. rend.*, **66**, 839, 1868.

making magnesia bricks at a much later date (see below), and that of Kraubat in Styria was known and used long before the Veitsch and other large Styrian deposits of breunnerite had been discovered.

Caron's method of procedure was to "dead-burn" the main mass of magnesite, after which it was readily broken to pieces so that the serpentine and quartz impurities could be separated. The product obtained was of a sandy, *i.e.*, crystalline nature, and as it would not bind alone it had to be mixed with caustic magnesia. Berzelius had previously indicated the property possessed by caustic magnesia of setting and hardening when moistened with water and afterwards dried, and it was this property that was taken advantage of by Caron. At a later date this property was accentuated by Sorel, who added the chloride and introduced the oxychloride cements.

The proportion of caustic magnesia used by Caron depended on the temperatures attained in calcination; but for magnesite dead-burnt at the temperature of molten steel, the amount of caustic magnesia used was about a sixth of the weight of the dead-burnt magnesia used. The mixture was wetted with 10 to 15 per cent. of water and moulded under pressure, after which it hardened on drying and became very refractory when subsequently baked.

It was due to the early work of the Geological Survey of Austria in the fifties of last century that the various deposits of spathic breunnerite in Styria and Lower Austria were discovered, and first described by F. Foetterle, one of the pioneer geologists of that Survey. Up to that time the best known and most used of the Styrian magnesites was that of Kraubat, a vein deposit of the cryptocrystalline type, and of good quality, resembling that of Salem and Greece. The saccharoidal magnesite of Kathrein in Austria was also used in those days, and seems to have been made into refractory bricks. Foetterle had a sample of sintered magnesia and a magnesia brick in the Austrian Survey Collection, and he appears to have fully appreciated the potentialities of Austrian breunnerite as raw material for the manufacture of sintered magnesia and magnesia bricks; but not until about a quarter of a century afterwards was its use in any large way for these purposes commenced. In the meantime, and even afterwards to some extent, the Germans appear to have followed the French practice in using compact magnesite of the Salem and Grecian type for the manufacture of magnesia bricks. The process of manufacture described in Germany at a much later date follows closely that described by Caron. Here again we may note that, according to C.

Bischof[1], the material used at Brieg in Silesia was the compact magnesite of Frankenstein, which resembled Grecian magnesite. The Brieg practice involved the use of caustic magnesia as a cement for the dead-burnt magnesia in making the bricks. Magnesium chloride was used in the cement, and the bricks were subjected to a pressure of 110 atmospheres in a hydraulic press. The bricks were then dried carefully in air, and as a result of this they assumed a denser and more compact character. After standing a week they were burnt in a Mendesheim gas furnace on a floor of magnesia bricks. The Brieg bricks had the following composition:—

	Per cent.
Magnesia (MgO)	80·9
Lime (CaO)	6·5
Silica (SiO_2)	4·8
Alumina (Al_2O_3)	1·6
Ferric oxide (Fe_2O_3)	6·8

According to Bischof high pressure must be applied in moulding the bricks if cracking is to be prevented, and the drying should be done slowly. The bricks should be perfectly dry before they are baked. The baking should be carried out at a uniformly high temperature, and the bricks should be cooled as slowly as possible.

Wedding[2] states in his description of the Austrian method of manufacture that the bricks are moulded in a hydraulic press working at a pressure of 300 atmospheres. He attaches importance to the removal of dust from the sinter. The dust consists mostly of lime and is easily separated because it slacks readily. Unless it is removed this lime reacts readily with silica, and is therefore injurious if Dinas bricks are built directly upon it. For making a basic hearth of magnesia he states that a mixture of finely-ground sintered magnesia and basic open-hearth slag was used.

F. Bleichsteiner also emphasizes the importance of removing lime from the sintered magnesia[3]. The dust obtained by screening the sinter is according to him largely calcareous and should be separated before the magnesia is pulverized for use. He recommends the use of sintered magnesia alone, without the addition of a caustic-magnesia cement, in the manufacture of bricks. The Veitsch company claims to adopt this method.

The possibility of brick manufacture from certain varieties of Austro-Hungarian dead-burnt magnesia without the use of cement appears to have been known for a long time. According

1 *Österr Zeit. f. Berg. u. Hutt.*, **41**, p. 27, 1893.

2 *Stahl und Eisen*, **13**, p. 279, 1893.

3 *Österr. Zeit. Berg. Hutt*, **40**, 355, 1892.

to C. Schimm[1] the magnesite of Mutnik in Hungary is specially adapted for use in this way, on account of its disseminated fibrous serpentine; but great elaboration in dressing appears to be necessary to reduce the amount of serpentinous impurity in the Mutnik material to the amount allowable in brick manufacture. Schimm states that the grains of pulverized sinter used in making magnesia bricks are screened to a limiting maximum size of about 2 mm. diameter.

Although the Veitsch Company claim to make bricks without binder, and Bleichsteiner states that this is the preferable mode of procedure, the accounts of Schimm and other writers on this subject seem to indicate that the manufacture of bricks from sintered magnesia alone is exceptional.

In a very interesting paper published in 1908, F. Cornu[2] dealt with the texture and composition of Austrian magnesia bricks as revealed by the polarizing microscope. He described and figured the peculiar honeycomb-like texture shown by thin sections of the Styrian bricks. This texture he attributed to the fact that the constituent granules were faceted crystals of periclase (crystalline magnesia). Artificial periclase had, however, long been known to mineralogists; and the sandy or crystalline material obtained by dead-burning the compact magnesite of India and Greece was already known to French and English scientific workers as an artificial form of periclase.

Cornu made a careful physical and chemical study of the constitution of Austrian bricks, and showed that the periclase granules were crammed with opaque and very minute particles. From the analysis of sinter and bricks he inferred that these minute particles, which seemed to show a cubic shape, consisted of magnesioferrite ($MgFe_2O_4$), a member of the spinel group of minerals. He also inferred from an analysis of an Austrian brick, that the vitreous cement in that particular case, not reckoning the iron oxide, had approximately the composition: lime 29, alumina 13, and silica 58 per cent. He further calculated that on the whole the brick consisted of about 94 per cent. of periclase, including the particles of magnesioferrite disseminated through it, and about 6 per cent. of vitreous cement *(glaskitt)*.

There appears to have been much variety of practice as regards the nature of the binding material used in the manufacture of magnesia bricks. Reference has already been made to the use of hydrated caustic-magnesia with or without magnesium chloride. According to Bischof a little iron oxide, silica or silicate may be added to modify the effect. In the

1 *Tonind. Zeit.*, 1905, Nos. 148 and 149, pp. 1968 and 1982.

2 *Centr. Min.*, etc., 1908, p. 305.

case of the Mutnik magnesite already mentioned, the self-binding property is conferred by the disseminated fibrous serpentine present. A serpentine binder appears to have been used largely also in the manufacture of bricks from Grecian, Norwegian and other magnesites. Clay to the amount of 15 per cent. or more is stated to have been used as a binder in some cases. Borax, dextrine, anhydrous tar and other materials have also been used, and the Veitsch Company is stated to have patented a mixture of dead-burnt magnesia, iron turnings and lime.

The degree of shrinkage suffered by a moulded and pressed brick during its final bake seems obviously a very important matter. According to Schimm the linear and volume shrinkages should not exceed about 5 per cent. and 15 per cent. respectively. The actual amount of this shrinkage depends on many factors and requires careful control if the finished bricks are to be sound and of uniform size. Factors which would appear to be important in determining the degree of shrinkage are the temperature of sintering, the grain-sizes in the crushed sinter of which the bricks are made, the nature and amount of the binding material, the degree of the moulding pressure and the temperature attained in the final firing operation. The apparent specific gravity of the crushed and roughly-sized sinter affords an indication of the thoroughness of the sintering, and the moulding pressure required to secure the proper amount of shrinkage in the finished product. It seems clear from the various descriptions given by different authors that the pressure applied in moulding the bricks is variable, and is regulated in accordance with the physical condition of the sinter from which the bricks are made.

We may sum up the views thus briefly reviewed as to the essential features of the manufacture of refractory magnesia as follows:—

(1) The finished products, whether as sinter obtained by dead-burning the raw magnesite, or as bricks produced by a second or further burning of the pulverized compressed sinter, should consist essentially of crystalline magnesia. The Austrian practice aims at obtaining a sinter containing at least 83 per cent. of magnesia. Lime, silica and alumina are regarded as undesirable ingredients and should not exceed 5 per cent., 6 per cent., and 2 per cent. respectively. Iron oxide is regarded as a desirable ingredient, but the amount of ferric oxide is not allowed to exceed 11 per cent. or so of the sinter.

(2) The dead-burning of the raw magnesite should be effective, since it is only the inert and comparatively dense, crystalline product (periclase), into which caustic magnesia

becomes transformed by prolonged heating at temperatures upwards of 1,400° C. that can be regarded as refractory. The kiln temperature required varies with, and must be adapted to, the nature of the raw material. The temperature required for the sintering of Styrian magnesite is said to range from 1,400° to 1,600° C., the average being about 1,500° C., whilst that required for Grecian magnesite is stated to be much higher; but there appears to be scope for useful investigation on this subject.

(3) The production of good magnesia bricks demands the use of pulverized sinter of good quality. The sizing of the grains, the nature and proportionate amount of the binder used where such is necessary, the pressure under which the bricks are moulded, the drying conditions, all these are controllable factors, and appear to be taken carefully into account in the Austro-Hungarian process of brick manufacture. The aim in this process seems to be to secure bricks the volume-shrinkage of which in the final burning operation does not exceed about 15 per cent., and the nature of which renders them immune from any considerable shrinkage under the furnace conditions for which it is designed to use them.

The manufacture of refractory magnesia thus clearly gives great scope for technical skill in management at every stage, from the careful dressing of the raw material and sintered product up to the production of finished bricks. It seems necessary to emphasize the importance of securing uniformity of quality in the raw material, since otherwise a manufactured product of standard quality can hardly be obtained. One may safely infer that, of the various factors which have contributed to the success of the refractory-magnesia industry of Austria-Hungary, one of the most important has been the careful standardization of the finished products, such as can only be attained by dressing the raw magnesite and dead-burnt magnesia so as to yield materials of steady quality.

Reference to recently published papers is avoided in this brief review, which, as a preface to the study of raw magnesite, aims chiefly at defining the requirements to which the raw material should conform. The refractory magnesia of commerce is in the form of either sinter or bricks, and, in dealing with the raw material, we do well to keep prominently before our minds the standard aimed at in the manufactured products, for only by so doing can we judge as to the relative merits of the different kinds of raw magnesite.

A Mineralogical Note on Magnesite.

Magnesite is one of a group of simple rhombohedral carbonates of which the most important from the refractories standpoint are *calcite* ($CaCO_3$), *magnesite* ($MgCO_3$) and *chalybite* ($FeCO_3$). These carbonates are closely similar to each other in their crystalline structure and symmetry, and their crystals are all characterized by three perfect cleavages, which cause them to split readily into rhombohedral fragments, such as we are familiar with in calcite and spathic iron carbonate. The polar (obtuse) angles of these rhombohedral cleavage fragments measure 105° 5′ for calcite, 107° 29′ for magnesite, and about 107° for chalybite.

The specific gravities for cleavage fragments of the three minerals are 2·72 for calcite, 3·02 for magnesite, and 3·88 for chalybite; and the molecular volumes are 36·8, 27·8 and 29·9 respectively. We may note that the polar angles and molecular volumes of magnesite and chalybite are in comparatively close agreement with one another, but differ substantially from those of calcite. In close correspondence we have the further facts that calcite and magnesite show only imperfect isomorphism, whereas the isomorphism between magnesite and chalybite is fairly perfect. A study of the isomorphism of the rhombohedral carbonates would take us too far from the purpose of this paper; but the subject is one deserving of notice by anyone interested in the mineral associations of magnesite considered as raw material from the refractories point of view.

The molecules of calcite and magnesite do not mix to form a well-graded isomorphous series. On the contrary they mix in the ratio 1 : 1 to form the mineral dolomite [$CaMg(CO_3)_2$] which is usually regarded as a molecular compound. We find, moreover, that when a dolomite rock contains calcium carbonate in excess of this ratio, the excess is present in the form of separate grains of calcite, which can often be mechanically separated from the dolomite. Impure dolomites of this kind are of very frequent occurrence, and may be described as calcitic dolomites or dolomitic limestones, according to which constituent is dominant. Similarly, when a dolomitic rock shows magnesium carbonate in substantial excess of the above-mentioned ratio, this excess is present not in a state of homogeneous admixture, but as separate grains of magnesite which can be mechanically separated from the dolomite. These facts concerning the petrology of dolomite and magnesite are easily intelligible when considered from the standpoint of the imperfect isomorphism of calcite and magnesite.

When we come to deal with mixtures of magnesium and iron carbonates, however, we find a very different state of things. The union of these two carbonates in a definite molecular ratio, as in pistomesite [$MgFe(CO_3)_2$], is unusual and merely accidental. Moreover, an excess of either the magnesium or ferrous carbonate over the amount required by this ratio is present as a homogeneous mixture, and not as a mixture of grains which can be mechanically separated. Breunnerite, the variety of magnesite from which Austro-Hungarian refractory magnesia is made, contains a variable percentage of ferrous carbonate in a state of isomorphous (homogeneous) admixture. This homogeneous condition of the breunnerite used in the manufacture of Austrian bricks is regarded as a feature of capital importance from the refractories point of view.

The terminology of the magnesite-chalybite series requires to be defined. The series is an important one from the economic standpoint, the chalybitic members as iron ores and the magnesitic members as refractories. In view, therefore, of the perfect isomorphism prevailing throughout the series, its subdivision on a definite basis seems clearly desirable. Perhaps the most convenient way in which this can be done, having regard to the meanings of mineral names already in use, is to subdivide on a percentage basis, as follows:—

	$MgCO_3$ per cent.	$FeCO_3$ per cent.
Magnesite	100 to 95	0 to 5
Breunnerite	95 to 70	5 to 30
Mesitite	70 to 50	30 to 50
Pistomesite	50 to 30	50 to 70
Sideroplesite	30 to 5	70 to 95
Chalybite	5 to 0	95 to 100

By this arrangement the names magnesite and chalybite are kept for the pure or almost pure carbonates, the limit of ferrous oxide and magnesia impurities respectively being about 3 per cent. The names mesitite, pistomesite and sideroplesite are here used in broader senses than is usual, but in such a way as to include the particular molecular mixtures to which the names have hitherto been largely restricted. It is convenient to use the name breunnerite in a definite sense, and the sense in which the name is here used includes the type breunnerite originally described by Haidinger. The material used for the manufacture of refractory magnesia in Austria-Hungary is also included under breunnerite, and it is quite useful from the refractories point of view to distinguish this material from the purer crystalline magnesite.

Without going into further detail concerning the rhombohedral carbonates, we may, for our present purpose, enumerate the chief members as follows:—

	Formula	Sp. gr.
Calcite	$CaCO_3$	2·72
Dolomite	$CaMg(CO_3)_2$	2·85
Ankerite	$2CaCO_3Mg(Fe)CO_3$	3·05
Magnesite	$MgCO_3$	3·02
Breunnerite	$Mg(Fe)CO_3$	3·1 to 3·45
Mesitite		
Pistomesite	$Fe(Mg)CO_3$	3·45 to 3·8
Sideroplesite		
Chalybite	$FeCO_3$	3·88

The specific gravity given above for magnesite as 3·02, is approximately accurate at the second decimal place for rhombohedral cleavage fragments of fairly pure magnesium carbonate. The specific gravity of the compact variety is always lower than this, and rarely exceeds 2·95. Values exceeding 3·02 for rhombohedral cleavage fragments free from pyritic and other such impurities indicate the presence of ferrous carbonate. Breunnerite has an average specific gravity of about 3·15.

An important fact concerning breunnerite is the conversion of the ferrous carbonate into a magnetic oxide on ignition in a reducing atmosphere. This is the cause of the blackness and magnetic character from the dead-burnt magnesia from which Austro-Hungarian bricks are made. In this respect breunnerite behaves like ankerite.

Much has been said concerning the part played by iron oxide in determining the comparative efficiency of Austrian dead-burnt magnesia both in the sintered and brick form. On this point we may here note that the virtue of the iron oxide in Austrian sinter lies in its binding and not in its heat-resisting properties. This binding effect is due to the comparatively low melting point of the iron compound formed. It is for this reason necessary to keep down the iron oxide percentage of the sintered product, in order to secure the binding effect without any serious sacrifice of refractoriness. We may note further that the blackness and magnetic permeability of the dead-burnt breunnerite facilitates dressing operations, and therefore makes possible the careful standardization of the product.

The dissociation temperatures of the rhombohedral carbonates have not been as fully investigated as they should be from a practical point of view, for they obviously have an

important bearing on the question of effective burning. According to Brill the dissociation temperature of magnesite is 445° C., whereas that of calcite is 825° C. Complete decomposition, however, requires higher temperatures than these, and depends to some extent on the physical condition of the mineral.

Chalybite appears to have a rather lower dissociation temperature than magnesite. According to Akermann it dissociates between 300° and 400° C., and so far as this may be of significance it operates in the direction of greater economy in the calcination of breunnerite as compared with purer magnesite; but it is perhaps not of much practical importance.

More important, perhaps, is the question of thermal conductivity. There is probably little difference of thermal conductivity between breunnerite and pure magnesia in the raw state, but the transformation of ferrous carbonate into magnetic oxide in the calcination of breunnerite might be expected to increase the conductivity substantially. This and the reaction of the iron oxide with the magnesia to form magnesioferrite in the sintered product, are doubtless factors of much significance in the readier dead-burning of breunnerite as compared with ordinary magnesite. The actual temperature of transformation of caustic (amorphous) into crystalline magnesia appears not to have been determined.

Calcined magnesite of the compact or Grecian type often shows a columnar structure, whilst spathic magnesite on the other hand retains its cleavage form when calcined, and shows rhombohedral fragments even in the sintered state. This feature is of some importance as regards the behaviour of the magnesite in the kiln.

The hardness and toughness of magnesite are variable. Spathic magnesite has a hardness of about $3\frac{1}{2}$. The compact variety is usually a little harder and may have a hardness of 4 or more according to the degree of silicification.

Spathic magnesite, on account of its ready cleavage, is easily broken up and ground, especially when it is coarsely crystalline. Compact magnesite of the vein type is sometimes brittle and may break with a conchoidal fracture. Nodular varieties on the other hand are apt to be very tough, and some kinds extremely so, presumably owing to their more complex texture. Compact vein magnesites are sometimes very tough, especially when, as in specimens obtainable from the magnesite of Kaapmuiden in South Africa, a considerable percentage of free silica is present in the form of a skeleton of quartz.

Economic Classification of Magnesites.

From the economic standpoint, perhaps the best way to classify magnesites is on the basis of texture and composition as follows:—

1. *Spathic breunnerite* (*e.g.*, Styrian).
2. *Spathic magnesite* (*e.g.*, Quebec, Washington, and Norwegian).
3. *Compact magnesite* [*e.g.*, Grecian, Californian, Italian, Indian (Salem) and Australian].
4. *Hydromagnesite* (*e.g.*, Atlin in British Columbia).

Spathic is a convenient descriptive term for those comparatively coarsely crystalline magnesites and breunnerites the constituent grains of which show cleavage. Compact or cryptocrystalline magnesite shows no cleavage, but it is generally firm in texture. Hydromagnesite is powdery or very friable.

It is of interest to note that differences in texture among magnesites correspond to differences in chemical composition. Deposits of spathic magnesite or breunnerite usually contain much more impurity than those of compact magnesite. Breunnerite is usually coarse in texture, and, as we have seen, characterized by a considerable percentage of ferrous carbonate isomorphously mixed with the magnesium carbonate. Spathic magnesite is usually less coarse in texture, and is almost free from admixture with ferrous carbonate.

Spathic magnesite and breunnerite generally occur in association with dolomite, and are therefore liable to contain much lime impurity. The admixture of this dolomite is less intimate in coarse-textured spathic breunnerites of Austria than it is in the closer-textured spathic magnesite of Quebec. Partly for this reason, and partly owing to the isomorphously mixed ferrous carbonate, the dressing of breunnerite and elimination of the dolomitic impurity is economically more feasible than in the case of the purer spathic magnesite.

Compact (cryptocrystalline) magnesite frequently includes an admixture of quartz, serpentine, or sepiolite, and is therefore liable to contain silica impurity; but except where its conditions of occurrence have allowed the infiltration of calcium carbonate, it is as a rule fairly free from lime impurity. This absence or low percentage of lime and iron renders it eminently suitable for the production of caustic magnesia as used in the manufacture of oxychloride cement, refractory paint, etc.

The following generalized analyses illustrate the chemical differences among these various types of dressed raw magnesite:

	Spathic breunnerite, Austria	Spathic magnesite, Quebec, Norway and Washington	Compact magnesite, Greece, India, and California	Hydromagnesite, Atlin, British Columbia
	Per cent.	Per cent.	Per cent.	Per cent.
Magnesia ..	38 - 44	38 - 47	47	42
me ..	1 - 3	0 - 10	0 - 2	0 - 2
Ferrous oxide, Alumina	2 - 7	2	1	1
Silica ..	1 - 5	1 - 3	1 - 3	1
Carbon dioxide	50	49 - 51	50	36
Water ..	—	—	—	19

The Austro-Hungarian material varies from pure magnesite to breunnerite, but consists predominantly of spathic breunnerite.

The large variation in the lime percentage of spathic magnesites is due to varying amounts of dolomite. Norwegian (Snarum) magnesite contains no lime. The material marketed in Washington State (U.S.A.) at the present time contains not more than about 2 per cent. of lime. Quebec magnesite (near Calumet), on the other hand, contains a considerable amount of dolomite and ranges up to 10 per cent. or more of lime.

Compact magnesite generally contains very little lime; but much Italian and some Grecian magnesite contains above the normal percentage, due presumably to the presence of calcite, which has found access to the veins through the medium of infiltering calcareous solutions that have traversed adjacent masses of chalk or limestone.

The hydromagnesite of Atlin is remarkable for its low percentage of impurities.

Fuller details of these and other magnesite deposits are given below.

Breunnerite.

It is customary to refer to all spathic magnesium carbonate as crystalline magnesite regardless of the percentage of ferrous carbonate present. The procedure adopted in this paper is to distinguish two types of spathic material, viz.: breunnerite and magnesite proper. Under the breunnerite type is included such spathic material as contains from 5 to 30 per cent. of isomorphously mixed ferrous carbonate. Spathic magnesium carbonate containing less than 5 per cent. of ferrous carbonate is classed as spathic magnesite and will be dealt with in the next section.

Breunnerite is widely distributed, but as yet only the Austro-Hungarian deposits have proved to be of economic value. As showing this wide distribution, reference is made

below to deposits containing the mineral in Canada, India and the United Kingdom, but many other occurrences are known.

Austria-Hungary.

The only deposits of the breunnerite type which have hitherto proved to be of economic importance are those of the metamorphosed Carboniferous strata of Styria, Lower Austria and Northern Hungary. Breunnerite is very abundant in this region, which is famous also for its spathic iron ores. It is noteworthy that the largest of the world's deposits of the mineral chalybite occurs at Eisenerz in Styria, whilst the world's largest deposit of breunnerite occurs at Veitsch in the same province. Spathic manganese ore (rhodochrosite) has also figured as a mineral of economic importance in Styria, and some of the deposits of spathic ore in this region are of a very mixed description. For information as to the geology and mineralogy of the breunnerite deposits of this region we are indebted chiefly to F. Foetterle,[1] J. Rumpf,[2] K. A. Redlich,[3] and F. Cornu.[4]

The Styrian and Lower Austrian deposits have the advantage that they are much nearer their Adriatic port than are those of Northern Hungary, and it is from them that most of the Austro-Hungarian magnesite hitherto exported has been obtained. They are situated in the region to the south-west of Vienna, along a tract extending westward from Semmering through the Mürz valley to the Tyrol. The chief deposits, taking them in order from east to west, are those of Semmering, Veitsch, Breitenau, Trieben, Radenthein and Dienten. Of these the largest and most important appears to be that of Veitsch, which is situated near Mitterdorf, a station on the South Austrian railway in the Mürz valley, in Styria.

The geological structure of this district, like that of so many parts of the Alpine region, is very complicated. The magnesite occurs as lenticular masses in a belt of foliated Carboniferous rocks belonging to the so-called greywacke zone. They are chiefly metamorphosed shales, sandstones and conglomerates, but include a limestone the fossils of which show it to be of Viséan (Lower Carboniferous) age.

The chief lenticular mass of magnesite near Veitsch forms the main part of the Sattlerkogels, a hill lying a kilometre or so to the north-west of the village. The summit of the Sattlerkogels is about 3,260 feet above sea level, and nearly a 1,000 feet

1 *Jahrb. k.k. geol. Reichanstalt*, **3**, 145, 1852; **6**, 68, 1855.

2 *Tscher. Min. Mitt.*, 1873, p. 263.

3 Various papers in *Zeit. f. prakt. Geol.*; and Doelter's *Handbuch der Mineralchemie*, Band 1, p. 243.

4 *Zeit. f. prakt. Geol.*, **16**, 449, 1908.

above the level of the Veitsch works. The magnesite is quarried on the slope of the hill in a series of terraces about 50 feet apart through a vertical distance of nearly 500 feet. The magnesite lens is three-quarters of a mile in length, and over a 1,000 feet in width. So far as can be judged from its disposition it probably extends to a considerable depth.

The dominant minerals of the Sattlerkogels magnesite deposit, as described by Cornu, are magnesite and dolomite. Scaly masses and films of talc are associated with the magnesite. Flakes of rumpfite (a hydrated silicate of magnesium and aluminium) are associated with the dolomite. Minerals occurring as infillings of cavities in the rock include quartz, dolomite, ankerite, calcite, rumpfite, pyrolusite and pyrites. Sulphide veins traversing the rock include quartz, pyrite, copper pyrites and fahlerz.

The magnesite occurs largely in coarse crystalline masses, and to some extent also in the condition of the so-called pinolite. The name pinolite is a refinement by Rumpf of the Styrian quarryman's "pinolistein," and applies to a rock consisting of crystals and aggregates of white magnesite in a matrix of schist (phyllite or talc-schist). The rock appears to have been formerly used as an ornamental stone in Austria, and derived its name from the supposed structural resemblance of the magnesite nodules to the cones of *Pinus pinea*.

The magnesite of Veitsch and many other localities in this region is of the breunnerite variety. It is greyish in colour when fresh, and contains sufficient isomorphously intergrown ferrous carbonate to blacken when calcined in a reducing atmosphere. In this respect it behaves like the white patches of ankerite seen in most specimens of English coal. It also behaves like ankerite in turning brown when exposed to the air. The amount of iron carbonate is variable, and various analyses show percentages ranging up to 13 or 14 per cent. A little pyrite (iron disulphide) is present in the form of scattered granules, more especially in the pinolite variety.

Although selected specimens of the Sattlerkogels breunnerite show so much variation in the percentage of ferrous carbonate present, there is comparatively little variability in the percentage of iron oxide in the sintered product as marketed. This may be seen from five analyses of sintered magnesite quoted by Cornu, which show variation between the following limits :—

	Per cent.
Magnesia (MgO)	85·53—90·07
Lime (CaO)	0·96— 3·52
Ferric oxide (Fe_2O_3) ...	7·43— 9·96
Manganese oxide (Mn_3O_4)	0·51— 0·76
Silica (SiO_2)	0·26— 1·34
Alumina (Al_2O_3)	nil— 2·22

A. Kern[1] quotes the following analyses of sintered magnesite from some of the more important Austrian localities:—

	Veitsch	Breitenau	Semmering	Sunk	Salzburg
	per cent.	per cent.	per cent.	per cent.	per cent.
Magnesia (MgO) ...	84·2	87·9	85·9	85·9	86·7
Lime (CaO) ...	2·5	2·8	3·0	4·5	2·0
Ferric oxide (Fe_2O_3)	8·4	5·5	5·3	6·8	5·9
Alumina (Al_2O_3) ...	—	0·7	0·1	1·4	1·1
Silica (SiO_2) ...	3·8	2·0	5·1	0·6	2·2

The smaller variation in composition shown by the sintered material as compared with selected specimens of the raw magnesite is doubtless due to the moderating effect of the crushing, dressing and sintering operations, which are accompanied by a fairly thorough mixing of the ground material.

According to Cornu (*op. cit.*), dolomite is abundant in the Veitsch magnesite deposits. It occurs partly as a fine-grained, greyish-black rock, containing in places dolomitized crinoid ossicles. Less commonly, according to Redlich, ossicles consisting of magnesite are found, whilst elsewhere similar crinoids are found in their unaltered condition as almost pure calcite. Redlich attaches much importance to these facts as indicating that the magnesite of Veitsch and similar deposits owes its formation to the replacement of limestone by solutions rich in magnesium bicarbonate. Weinschenk holds a somewhat similar view, but whereas the latter thinks the magnesium solutions escaped from intrusive granites, Redlich is of opinion that the solutions were derived from basic intrusions corresponding to the diabase tuffs and other basic rocks which are so abundant in this region of the eastern Alps. Rumpf held the view that the magnesite was of sedimentary origin, and that it was precipitated from the water of hot springs with the mud that accumulated in shallow depressions of the floor of a warm sea. Kern holds a somewhat similar view, and attributes the existing crystalline condition to thermal metamorphism.

In addition to the fine-grained dolomite, the Veitsch magnesite deposit contains a large amount of coarsely crystalline and yellowish-white masses of dolomite. Large cleavage fragments of 10 to 20 cm. edge are obtainable from these masses of coarse-textured dolomite which are enclosed in the Veitsch breunnerite. Such included lumps of dolomite are naturally regarded as objectionable by the quarrymen, and have to be eliminated as far as possible either by cobbing in the quarry,

[1] *Glückauf*, **48**, 281, 1912.

or in subsequent dressing operations, as otherwise the product obtained would contain too much lime. The colour of the dolomite lumps helps the quarrymen to detect their presence.

According to Cornu, dolomite occurs in yet another way in the Veitsch magnesite deposit, viz., as crystals lining the cracks and cavities in the rock; these crystals show zonary bands of iron oxide and pyrite, the pyrite granules being largely oxidized. Associated with the dolomite crystals in these cracks and cavities are small crystals, insignificant in total amount, of quartz, calcite, aragonite, pyrolusite and pyrite.

In view of the intimacy of the association of dolomite and breunnerite at Veitsch, one might expect that the dolomite would be largely ankeritic. This does not seem to be the case. Analyses of the dolomite show that it is fairly steady in composition and contains only 1 or 2 per cent. of iron carbonate. It is very fortunate that this is so, for if the dolomite were largely ankeritic, it would be difficult if not impracticable to keep down the lime percentage in the sintered product. The elimination of fairly pure dolomite from breunnerite in dressing operations is an easy matter, whereas the elimination of normal ankerite would be practically impossible.

Lime is regarded as an objectionable ingredient in calcined magnesia, and efforts are made to keep its percentage as low as possible in the sintered product. Austrian sinter usually contains a variable but small percentage of lime, which we may safely attribute to the presence of dolomite, perhaps slightly ankeritic, in the raw material.

According to J. Hörhager[1] and A. Kern[2] the quantity of waste rock obtained in quarrying may amount to about two-thirds of the total bulk of the rock. The freshly-quarried material is cobbed to free it as far as possible from coarse fragments of impurity such as schist, dolomite and quartz, and the lumps are sorted. The cleaner portions of the rock are reduced to pieces about head-size. Less pure material has to be broken into smaller pieces, of fist-size, and its dressing involves a considerable loss of magnesite in the form of fragments smaller than nut-size, which are too small to be burnt in shaft kilns. The raw magnesite thus obtained in the quarries at Sattlerkogels near Veitsch is readily transported by aerial ropeways and shoots to the sintering kilns at the foot of the hill.

The sintering temperature varies from 1,400° C. for breunnerite containing a considerable percentage of iron oxide to 1,700° C. for magnesite poor in iron oxide; but, however easily the material sinters it is, according to Hörhager, desirable

[1] *Stahl und Eisen*, 31, 955. 1911.

[2] Op. cit.

to carry the temperature up to at least 1,500° C., and this temperature seems to be exceeded as a rule in Styrian shaft kilns.

According to L. C. Morganroth,[1] kilns of the rotary type have been installed at several places in Austria, powdered coal being used as fuel, but they suffer from the disadvantage of yielding a larger percentage of fines.

Sintering does not destroy the rhombohedral form of the magnesite fragments, and a microscopical examination of the powdered sinter shows clearly the characteristic texture that has been so well described by Cornu.

According to Hörhager the amount of fuel required to sinter Austrian magnesite is variable, and depends on the amount of ferrous carbonate present; but with good flaming brown coal having a calorific value of 6,000 calories, the amount of coal required is from 0·3 to 0·4 ton per ton of sintered magnesia produced. Kern puts the fuel requirement at 0·5 ton of brown coal (calorific value 4,000 calories) per ton of sintered magnesia produced.

The crushed sinter, as a rule, requires to be further dressed to eliminate impurities, for these are far from having been completely removed before sintering. For this purpose the grains are classified mechanically. Much of the caustic lime or calcined dolomite falls to dust and is easily eliminated in the finest screenings. The coarser grains are readily dressed by hand-picking, the light-coloured and therefore readily-distinguished impurities, such as talc, calcined dolomite and tridymitized quartz being easily removed. The less coarse material is presumably in large part marketed in a comparatively impure condition, or otherwise requires to be treated magnetically to remove particles of schist, silica, calcined dolomite and other impurities that are magnetically non-permeable. This magnetic treatment, which involves much waste, adds considerably to the cost of the material, and is presumably only carried out when it is necessary to concentrate the sintered magnesia and thus secure a more refractory product.

In addition to the sintering and dressing plant near Veitsch there are works at other localities in Styria, including those at Breitenau and Trieben. There are also works at Eichberg near Gloggnitz, in Lower Austria.

At Veitsch, transportation of the refined sinter from the kilns to the goods depôt at Wartberg station is by an aerial ropeway over four miles long. The works at Breitenau are situated at the foot of the Hochlantsch (5,700 feet), where terrace-quarrying and other working conditions closely resemble

1 *Bull. Amer. Inst. Min. Eng.*, 1914, p. 2350.

those at Veitsch and Eichberg. The Trieben works are near the station at Trieben, and are some three miles from the deposits at Sunk where the magnesite is quarried. The deposit at Radenthein has been worked since 1908 by American capital, and from that date down to 1915 large quantities of sinter were shipped to Philadelphia, New Orleans and New York.

The oversea exports of sintered magnesia from all these works in Styria and other parts of Austria were shipped at the port of Trieste.

The Austrian magnesite formation stretches eastward beyond Vienna into northern Hungary, where large magnesite deposits are quarried between Jolsva and Nyustya in the Gömör district. These northern Hungarian deposits have much in common with the Austrian, and in spite of their great distance inland from the Adriatic there have been considerable oversea exports in pre-war days from Fiume, to which port they were railed some 360 miles for shipment to various parts of Europe and America.

A factor of much economic importance in the magnesite industry of Austria-Hungary is the abundance and accessibility of brown coal which is used in the sintering kilns. If to this we add the further considerations that the deposits are large and easily quarried, that they are within easy reach of transport facilities, and that labour is cheap, we see that Austrian magnesite mining has all the prime essentials of a successful and enduring mineral industry. It is necessary to give due prominence to these considerations if we wish to understand the success that Austrian magnesite-mining has achieved in the past, and the competitive pressure it is likely to exert in the future.

There are numerous occurrences of breunnerite in the form of scattered small crystals in talc-schists in various other parts of Austria, but such occurrences cannot be economically worked. Only the massive deposits of the Veitsch type can be quarried and worked at a profit, and even some of these are unable to compete with the largest and most favourably situated deposits.

Canada.

Breunnerite occurs in various parts of Canada. Occurrences were reported a long time ago[1] in the Sutton and Bolton townships of Brome County, Quebec. On the twelfth lot of the seventeenth range of Sutton the mineral forms a band a foot thick; it is associated with chrome mica, dolomite and steatite in grey mica-schists. A fairly pure and slightly coloured fragment of this breunnerite gave 83·35 per cent. of magnesium

1 *Report of Progress to* 1863, *Geology of Canada*, 1865.

carbonate, 9·2 of ferrous carbonate, and 8·03 of insoluble matter (*op. cit.*, page 457).

An occurrence on the seventeenth lot of the ninth range of Bolton is stated to be a bed twenty yards in width, lying between steatite and impure serpentine. A sample of this gave 59·13 of magnesium carbonate, 8·32 of iron carbonate and 32·2 of insoluble matter which consisted almost wholly of quartz (*op. cit.*, page 458).

Of other breunnerite occurrences in Quebec, mention may be made of that described by B. J. Harrington on the fifteenth lot of the first range of Melbourne in Richmond County[1]. The breunnerite is scattered through serpentine in the form of small irregular crystalline masses of a pale brown colour, and constituted 15½ per cent. of the specimen examined by Harrington. It gave on analysis:—

	Per cent.
Magnesium carbonate... ...	82·23
Ferrous carbonate	14·84
Calcium carbonate	1·93

The serpentine matrix in which the breunnerite is embedded showed the following composition:—

	Per cent.
Silica	42·79
Magnesia	36·54
Ferrous oxide	6·05
Manganese oxide	0·12
Chromic oxide	0·29
Nickel and cobalt oxides ...	0·37
Water (by ignition)	13·37

L. W. Bailey and G. F. Matthew record the occurrence of a vein of magnesite several feet wide in association with chloritic schist on the bay shore of St. John County near West Beach (New Brunswick).[2]

R. G. McConnell[3] found ferruginous crystalline magnesite abundantly in the neighbourhood of the Big Salmon River, just below Island Lake, Lewes River, in the Yukon District. This magnesite, which is associated with chromite and chrome mica, forms bands up to 50 feet thick in a series of slates, schists and serpentines. Another occurrence of a similar type was found by McConnell some 300 miles north-west of the foregoing locality, on the east side of the Yukon River about 1½ mile above the Indian River.

More recently D. D. Cairnes has reported the occurrence of numerous beds of magnesite up to 10 feet or more in thick-

1 *Geol. Surv. of Canada*, 1874-75, p. 308.

2 *Geol. Surv. of Canada*, 1870-71, p. 237.

3 *Geol. Surv. of Canada*, new series XI, 15 B and 16 B.

ness intercalated among slates and dolomites at various places on the Stony Fork of the Black River, Yukon River.

These various occurrences in the Yukon area, like many other Canadian occurrences, are too remote from transport facilities to be of any economic importance at present, but they are of much interest as showing the widespread distribution of the mineral in Canada.

India.

An occurrence of breunnerite at Huliyar in the State of Mysore, India, has been described by Sir Thomas Holland.[1]

The Huliyar rock consists of breunnerite crystals, varying in size from small granules up to crystals of an inch across, lying in a dark greenish-grey, fine-grained matrix of talc and picrolite (picrolite is a brittle fibrous variety of serpentine). Magnetite in the form of disseminated granules, or as patches and bands of dust, is present both in the breunnerite and the matrix. The breunnerite encloses also occasional shreds of talc and picrolite, and granules of pyrite.

The specific gravity of a large piece of rock was found to be 2·95, that of the matrix 2·84, whilst that of the breunnerite was 3·17. The sample examined showed a mixture of 35 per cent. of breunnerite and 65 per cent. of matrix. The following is an analysis of a specimen of the breunnerite of specific gravity 3·17, and the estimate of its mineral composition as given by Sir Thomas Holland:—

Analysis.	Per cent.
MgO	39·20
FeO	8·27
Fe_2O_3	2·93
CaO	trace
CO_2	47·01
Insoluble	1·57
	98·98

Estimated mineral composition.	Per cent.
Breunnerite	94
Magnetite	4·4
Talc and picrolite	1·6
	100·0

The analysis of the matrix and its estimated mineral composition are given as follows:—

Analysis.	Per cent.
SiO_2	42·20
Fe_3O_4	13·59
MgO	30·41
CO_2	5·30
H_2O	7·73
S	0·11
	99·34

Estimated mineral composition.	Per cent.
Breunnerite	10·5
Pyrite	0·2
Magnetite	10·0
Talc and serpentine	79·3
	100·0

[1] *Mem. Geol. Surv. India*, **34**, 1, 1901.

The relation of the Huliyar deposit to the surrounding crystalline schists could not be ascertained, but Sir Thomas Holland presumes that it is a metamorphosed peridotite intrusion, and that the formation of the breunnerite is due to the action of carbon dioxide on the rock immediately, or at any rate very soon, after intrusion. He compares the deposit with that at Salem, points out that quartz impregnated with carbon dioxide is commonly associated with the peridotite intrusions of this region, and shows reasons for attributing the formation of the magnesite deposits generally to the action of magmatic water and carbon dioxide. He suggests that the water and carbonic acid which caused the metamorphism of the Huliyar deposit were held in the peridotite magma at the time of intrusion, and that they did their work of transformation in the last phase of the intrusive activity, being liberated from the magma after the olivine had mostly crystallized out.

There appears to be no information available as to the extent of this deposit, but the nature of the rock is such as to suggest that the mining and dressing costs would be prohibitive.

United Kingdom.

Occurrences of breunnerite in talc-schists have been reported to occur in various parts of the British Isles, as at Norwick Bay, Unst, Shetland Isles, where the conditions of occurrence appear to be of the normal type. None of these deposits in the British Isles is known to be of any considerable size, and so far as can be judged from descriptions available, the type of rock is such that, even if the deposits were large, the costs of dressing the raw material would be prohibitive. It can hardly be said, however, that British occurrences have received the attention which, in view of present conditions, they appear to deserve, and a fuller description of the areas where they occur seems to be desirable.

Spathic Magnesite.

Under this heading it is convenient to include those crystalline magnesites in which the magnesium carbonate is free from admixture with ferrous carbonate, or contains not more than 5 per cent. of this constituent.

These spathic magnesites frequently show a saccharoidal texture and resemble crystalline marbles. Calcite, dolomite and magnesite all assume this particular texture, and often bear a very remarkable and delusive resemblance to each other, so much so that only by careful tests can their identity be established. It is well worth while to emphasize this fact, for no

specimen of the saccharoidal-marble type should be regarded as a limestone, dolomite or dolomitic limestone (one of which it usually is) without definite proof of identity. The specific gravity test, judiciously applied, is one of the simplest and best, and is readily confirmed by solubility and other chemical tests. The specific gravities of pure crystalline calcite, dolomite and magnesite are respectively about 2·72, 2·87 and 3·01. The associations in these spathic types are usually calcite with dolomite, and dolomite with magnesite. A specific gravity between 2·75 and 2·85 therefore indicates a dolomitic limestone, whilst one between 2·9 and 3·0 indicates a dolomitic magnesite. A striking instance of the caution needed in dealing with such samples was experienced some years ago by the writer when examining specimens of white crystalline "limestone" from Ceylon. Two of these were identical in texture, and to all appearances in mineral composition also. Both contained small granules of apatite and flakes of graphite, which are of common occurrence in such rocks, and so far as appearances could be trusted they seemed to be identical. The carbonate portion of one sample, however, had a specific gravity of 2·87 and proved to be pure dolomite, whilst the carbonate of the other had a specific gravity of 3·01 and proved to be almost pure magnesite.

Recent work in areas where metamorphosed dolomites occur has shown that saccharoidal magnesite occurs more frequently than might have been supposed, and it is especially worthy of note that the spathic magnesites of both Quebec and Washington State were used as marbles for building purposes prior to their recent extensive development and use as sources of refractory magnesia.

Canada.

Among the most important examples of spathic magnesite at the present time are the deposits near Calumet in Argenteuil County, Quebec, which were first observed in the year 1900, and have been described at length by M. E. Wilson in a memoir issued recently by the Geological Survey of Canada.[1] The chief localities are in the townships of Grenville and Harrington, where magnesite occurs in a formation known as the Grenville series, which is of early pre-Cambrian age. Work was commenced on these deposits in a small way in 1907, at a locality about 12 miles from the Canadian Pacific Railway, the nearest station being Calumet.

1 Magnesite deposits of Grenville District, Argenteuil County, Quebec, Memoir 98, *Dept. of Mines, Canada*, 1917. See also the various Annual Reports on Mining Operations in Quebec.

The Grenville series is made up of metamorphosed sedimentary rocks consisting chiefly of gneisses, quartzite and crystalline limestone. Associated with these is a series of intrusive pyroxenic igneous rocks (the Buckingham series) ranging in composition from syenite to gabbro and pyroxenite.

The dominant intrusive rocks of the district, however, are huge bosses of gneissose granite and syenite of later pre-Cambrian age than the rocks of the Grenville and Buckingham series into both of which they intrude. Even this does not complete the record of the changes that took place during pre-Cambrian times in this remarkable Eastern Canadian patch of the earth's crust, for there are still later intrusions of dolerite and granite the geological relations of which have led the Canadian geologists to regard them also as pre-Cambrian.

With the exception of a small area occupied by older Palæozoic rocks, and a superficial covering of Pleistocene detritus on the lower ground, the Grenville district is occupied entirely by pre-Cambrian rocks, and it is in the oldest of these, the Grenville series, that the magnesite occurs, as a metamorphic rock associated with dolomite and serpentine, usually in close proximity to the pyroxenic rocks of the Buckingham series.

The rocks of the Grenville series have offered less resistance to denudation than the gneissose granites, and the larger valleys of the district have therefore been carved out of the former rocks. It is in these valleys that the magnesite deposits are found cropping out in the form of ridges which pierce the Pleistocene sands and clays, and which may be as large as 1,000 feet long and 300 feet wide

The rocks of the Grenville district have suffered extensively from crumpling and deformation, as a result of which well-marked foliation and lenticular structure have been developed. The magnesite itself occurs in lenticular masses and shows a banded appearance due to the streaky distribution of the serpentine it contains. The intimacy of association between the magnesite and the serpentine is shown by the manner in which such streaked masses of magnesite pass gradually into massive serpentine.

Still more intimately associated with the magnesite is the mineral dolomite, which is almost invariably present in scattered irregular pieces through the mass; the dolomite is also present in the form of separate lenticular masses. Other minerals found associated with these magnesite-dolomite-serpentine masses of the Grenville series are diopside, phlogopite, quartz, talc, pyrite, zinc-blende, magnetite and graphite.

Diopside is particularly abundant near the contact of the magnesite with the Grenville quartzite, which adjoins it in places.

Masses of quartz have been found in the magnesite at one locality, and it is thought that these may be portions of Grenville quartzite that have become incorporated in the magnesite.

Phlogopite and talc are associated with the serpentine and diopside. Grains and cubes of pyrites occur commonly scattered through the serpentine and dolomite, but are not usually found in the magnesite; and zinc-blende is occasionally associated with the pyrite. Magnetite is found as octahedral grains in the dolomite. Graphite is scarce, and, as is usually the case in such rocks, is disseminated in the magnesite in the form of fine crystalline flakes.

Wilson attributes a metamorphic origin to the Grenville magnesite, and concludes that it has been formed by the replacement of the limestone member of the Grenville series through the agency of magnesia-rich solutions emanating from the basic intrusives of the Buckingham series. According to him the probable order of events in the formation of the deposits was as follows: (1) the silication of limestone to diopside and the formation of phlogopite in places; (2) formation of serpentine in places; (3) replacement of limestone by dolomite; (4) replacement of dolomite by magnesite; and (5) the alteration of diopside to serpentine. Wilson's view as to the origin of the Grenville magnesite is thus essentially the same as that held by Redlich with regard to the Styrian deposits (see above).

Some idea of the magnitude of certain of the Grenville district deposits may be gathered from the dimensions recorded for Outcrop No. 3, Lot 15, Range XI, in Grenville township. This deposit has a horizontal extent of 30,000 square feet, a proved average depth of 125 feet, and is estimated to contain 60 per cent. of magnesite. The estimated quantity of magnesite available in this particular deposit is 187,500 tons, and 71 samples of magnesite taken from the deposit show amounts of lime ranging from 5 to 15 per cent.

The Grenville magnesite is cobbed in the quarries to remove the impurities so far as this is economically possible. The colour and appearance of the material assists the quarrymen in their hand-dressing operations. The dolomite is dull-white or coarsely crystalline. Cream-white to glistening magnesite of medium to fine-grained texture contains as a rule less than 7 per cent. of lime, whereas the pure-white variety contains rather more lime, up to 11 or 12 per cent., and the

grey varieties may contain still more lime. A laboratory test is stated to have shown that, after calcination, the dolomite slakes to a smooth paste and can be washed away, leaving a residue of purer magnesite.

Although dolomite is invariably present in the deposits, it has been shown by diamond-drilling and other development work that there is a large amount of magnesite containing on the average not more than from 7 to 10 per cent. of lime.

The following summary by Wilson[1] shows the amount of magnesite and magnesite-dolomite in sight on various properties at the time he examined them:—

Property	Magnesite with less than 12 per cent. lime	Magnesite-dolomite with more than 12 per cent. lime
	Tons	Tons
Lot 13, Range I, Harrington township	25,000	8,000
,, 18, ,, XI, Grenville ,,	15,000	6,000
,, 15, ,, XI, ,, ,,	418,000	186,300
,, 15, ,, X, ,, ,,	2,500	4,000
,, 15, ,, IX, ,, ,,	226,400	279,400
Totals	686,900	483,700

Further exploration in the Grenville district is likely to result in the discovery of other deposits, and a large increase in the proved reserves of magnesite. According to Wilson it is probable that extensive masses of magnesite occur beneath the superficial covering clay in the low-lying parts of the district.

A deposit of spathic magnesite near Orangedale, Inverness Co., Nova Scotia, was described recently.[2] A trial output of 30 tons of this has been tested by the Nova Scotia Steel & Coal Company. An analysis showed 90·8 per cent. $MgCO_3$, 1·6 lime, 1·71 ferric oxide, 1·01 alumina, and 0·30 silica.

United States.

Large deposits of spathic magnesite have been opened up since 1916 in the State of Washington, U.S.A. These deposits are situated in Stevens County, about 60 miles north of Spokane. The magnesite in this area is described as resembling marble or dolomite in texture; it occurs in extensive and thick beds which can be quarried easily and cheaply.[3] The deposits are thus comparable with those of Quebec, and, like the latter, have been quarried for use as marble. The magnesite of Washington, however, seems to be of better quality than the

1 Op. cit., p. 62.

2 *Summary Report Geol. Surv. Canada*, 1916, p. 277.

3 *Min. Res. U.S.*, 1916, published in 1918.

Canadian, as it contains less lime. Several large quarries have been opened up in Stevens County, and some of these are within five miles or so of the Chewelah railway station.

As described by R. W. Stone[1] the deposits of Washington State appear to be of large size. One lens of magnesite in which two quarries have been opened near Brown's Lake, has a length of 1,000 feet, a thickness of 200 feet, and is worked on a quarry face 75 feet in height. The magnesite is underlain by slate, overlain by quartzite, and is associated with a compact igneous greenstone.

At the Keystone quarry, where magnesite was formerly quarried as a marble, magnesite occurs mixed with dolomite in a large lens in which it is estimated that there is 1,000,000 tons of magnesite in sight.

Another, known as the red marble deposit, on account of its colour, though it contains very little iron oxide, is a lens about a quarter of a mile long and from 200 to 300 feet thick, associated with quartzite, slate, schist and igneous greenstone. It is estimated that this deposit may contain not less than 2,000,000 tons of magnesite within 50 feet of the surface, assuming that 50 per cent. of the rock is magnesite.

According to R. W. Stone (*op. cit.*), the Washington magnesite commonly contains from 42 to 45 per cent. of magnesia and 1 to 2 per cent. of ferric oxide. The magnesite sold in the raw state is specified as containing not more than 3 per cent. of silica and 2 per cent. of lime.

In 1917 the raw and calcined magnesite were delivered on the railway at Chewelah (Wash.) for $7·5 per ton and $32·5 per ton respectively.

The activity of recent developments in these Washington quarries may be judged from the fact that the output, which was only 715 tons in 1916, reached about 100,000 tons in 1917, and is expected to exceed this in 1918. The magnesite is being transported largely to Chicago and the Eastern States for use in steel- and copper-furnace linings, and has to bear a freight-charge of $10 or more per ton.

I am indebted to the Director of the United States Geological Survey for two very interesting specimens typical of the magnesite produced at the quarries near Valley and Chewelah in Stevens County, Washington, and for analyses of samples taken from the bunker or stock pile represented by these two specimens. The magnesite near Valley is of different colours, and may be white, grey, black, pink and red. It is all crystalline, and resembles marble. One of the specimens

1 *Eng. & Min. Jour.*, **105**, 665, 1918.

is a red magnesite from the Red Marble quarry of the American Mineral Production Company, Valley, Washington. The other is a white magnesite from the Allen quarry of that company at Valley, Washington. The following are the analyses, which are remarkable as showing that a sample of the red magnesite, which might be expected to contain an appreciable percentage of iron oxide, contains very little, and indeed rather less than that of the white magnesite:—

	Red Magnesite, Red Marble Quarry	White Magnesite, Allen Quarry
	Per cent.	Per cent.
Silica (SiO_2)	4·27	0·46
Ferrous oxide (FeO)	0·78	1·01
Lime (CaO)	1·07	0·31
Magnesia (MgO)	45·02	46·23
Carbon dioxide (CO_2)... ...	49·51	50·32
	100·65	98·33

In a paper that has appeared just recently (*Econ. Geol.*, 1918, **13**, 381), O. P. Jenkins deals with the geology of the magnesite deposits of Washington State, and accounts for their formation by solution replacement due to the action of circulating underground solutions containing magnesium compounds which were derived from the basic intrusions. The rocks are supposed to have been limestones or dolomites originally. He thinks that the change was brought about for the most part after, rather than during, the process of intrusion.

Other Localities.

Crystalline magnesite has been described from many other localities, including Southern Norway, Ceylon, the Urals, Kathrein in Styria, and other localities.

Of these the occurrence near Snarum in the Modum district of Southern Norway is of much interest as a special type of white spathic magnesite. The locality where this is mined is about 35 miles from Drammen, and is conveniently situated for shipment either at the latter port or at Christiania. The magnesite is found as veins averaging 13 feet thick in a mass of serpentine which is associated with schists and quartzites. The magnesite contains serpentine impurity, which is used in admixture with the magnesite for sintering and brick-making

as in the case of Grecian magnesite. There is a brick-making plant at the mines, and the bricks are stated to be superior to Austrian bricks in their refractory qualities. A characteristic feature of the Snarum magnesite is the absence of lime. The following are analyses of the magnesite of Snarum and a brick made from it:—

	Magnesite sp. gr. 3·02 per cent.	Magnesia brick per cent.
Magnesia	47·29	83·6
Silica	—	9·3
Alumina	—	2·0
Ferric oxide	0·79	4·6
Carbon dioxide	51·45	—

A specimen of white crystalline magnesite from Randeniya, Wellawaya, Uva Province, Ceylon, examined by the writer, contains a small amount of granular blue apatite, but otherwise consists of practically pure magnesite, and gave the following analysis at the Imperial Institute:—

	Per cent.
Magnesia	47·60
Lime	1·31
Silica	0·50
Ferric oxide and alumina ...	trace
Phosphorus pentoxide... ...	0·09
Loss on ignition	50·52

No information is available as to the extent of these deposits of crystalline magnesite in Ceylon.

Compact (Cryptocrystalline) Magnesite.

This type of magnesite usually occurs in the form of veins traversing peridotite (olivine-bearing) rocks, or the serpentines which have been formed from these rocks by hydration. The crystallization is very imperfect. The constituent granules or particles are microscopically small, and the material appears to consist in part of a non-crystalline paste. This texture is of the kind named cryptocrystalline by petrologists, and is associated with a very compact condition.

The physical condition of compact magnesite is largely bound up with the condition of the silica, which appears to be always present, though in varying amounts, and which may be in the form of crystalline or non-crystalline magnesium silicate, or in the form of free silica, usually quartz.

Geological age is probably an important factor in connection with the mineral condition of the silica and therefore with the physical properties of this type of magnesite. Some

compact magnesites, such as those of Elba in Italy, Bissel in California, and other places, readily form a paste with water, and this is probably due to the presence of colloidal matter in the form of magnesium silicate, or silica, or perhaps even hydromagnesite, which takes up water and causes the material to fall to pieces when wetted. In this respect such magnesite invites comparison with common clay. When geologically young, and unaffected by the compacting process which becomes accentuated with geological age, common clay is plastic and makes a paste with water; but when geologically old or metamorphosed it passes over into the non-plastic forms of shale, mudstone or slate.

Only the geologically young cryptocrystalline magnesites are likely to contain colloidal silica or magnesium silicate or possibly hydromagnesite, and when this is considerable in amount and not too dessicated, the magnesite will yield a paste with water. This colloidal matter is unstable and tends to break up into magnesite and crystalline silica as age advances, or perhaps to reproduce olivine and serpentine as the result of further metamorphism.

It may be suggested that the presence of colloidal siliceous matter at the time of deposition of the compact magnesite is probably the explanation of the texture of this kind of magnesite. Such colloidal matter has an inhibiting effect on crystallization.

The chief deposits of compact magnesite are those of Greece, California, India, Australia, South Africa and Italy. These and other deposits are described below.

Greece.

The best-known and hitherto the most productive of the world's deposits of compact magnesite are those of the Island of Eubœa in Greece. These deposits were described in detail a few years ago by J. Hogg.[1] For the details here given I am chiefly indebted to his paper and to the Anglo-Greek Magnesite Company, who have taken the trouble to provide me with a report dated June, 1918, dealing with the Grecian industry, and have given me permission to use the information for this paper.

Most of the deposits so far exploited in Eubœa lie in the northern part of the island, where there is a belt of serpentine six to nine miles in width and fifteen miles in length. This serpentine belt is bounded on the east and west by the sea, and on the north and south by Cretaceous limestone.

1 *Trans. Inst. Min. Eng.*, 46, 128, 1914.

The magnesite occurs as white compact masses in the form of veins, lenticles or irregular masses in the serpentine. The dimensions of the magnesite bodies are very variable. The width of the bodies varies from 6½ feet up to 130 feet, and the greatest length so far observed in a vein is 500 feet.

The greatest depth at which the deposits are worked to-day in Eubœa is about 660 feet, which depth has been reached in the Mantudi mine on the north-east coast of the island. The average depth of mining operations elsewhere does not exceed 200 feet. Hogg thinks that the veins are not likely to extend to any great depth. At the mine where he was stationed a depth of 200 feet had been reached. He observed that the vein continued in depth beyond this level, but that it was much narrower than it had been at shallower levels, whilst a number of veins worked at adjacent mines pinched out at a comparatively shallow depth.

The more important of the Eubœan magnesite deposits may be classed in three groups, as stated below; but these deposits are not all being worked at the present time, as war-time conditions have restricted transport facilities, and the output is disposed of under the control of the Britsh and French Governments:—

(1) *The Limni-Galataki group*, situated on the southern side of the serpentine belt. These comprise the Limni community mine (including the Vathia Kanalia deposits), the deposits of the Galataki concession, and the Trupi village deposit. The Galataki concession includes the Ypsili Rachi, Adralee, Hortocopi, Pefteli, Kakavos, Moraitis, Archangelos, Strongyli and Trupi.

Of this group, only the deposits of the Galataki concession are being worked regularly at present. The distance of these deposits to the loading port is 9 miles by railway (2 ft. gauge) and 4 miles by rope line. The rope line is worked on the double rope system, and is capable of conveying 200 tons of mineral per working day of ten hours.

(2) *The Mantudi-Pyli group*, situated on the north-eastern coast of the island, including the Mantudi or Elafosouvala, Dafnopotamos, Livadakia, Atalantos, Stavros, Maccas, Haghia Triti, Aspri Vrysi, Yerorevma, and Plakaries mines.

The port of shipment for the Mantudi concession is Kymassi, which is connected with the mines by means of a 2 ft. gauge railway 2½ miles in length. A rope line connects the two outlying concessions of Plakaries and Yerorevma with Mantudi.

The port of shipment for the Haghia Triti, Maccas and Stavros mines is Pyli, which is connected with the mines by

a rope line capable of transporting 100 tons per working day of ten hours. This rope line is $3\frac{3}{4}$ miles long, with an intermediate station at Maccas and Stavros nearly two miles from Pyli Bay.

(3) *The Chalcis group*, situated east-south-east of Chalcis, including the Afrati village, Afrati, Gerakari and Phylla mines. Of this group only the Afrati is working at present. The transport of the magnesite mined in the Afrati district is by carts to the loading port of Lefkandi in the Euripo channel.

The Eubœan deposits were formerly worked open-cast, but in recent years underground mining has been resorted to. In the first instance the method adopted was to work the veins by wide stalls, pillars being left to support the roof, but this has more recently given place to the long-wall method of working.

The crude magnesite obtained by mining is hand-dressed by girls, as much serpentine and calcite as possible being eliminated in this way. The hand-dressed raw material is then transported, as already indicated, to the ports of shipment, where part of it is calcined. The material to be calcined is, however, still further dressed and broken into lumps of convenient size before it is fed into the kilns. The material is shipped partly in the raw and partly in the calcined state.

The following analyses show the chemical composition of typical samples of Grecian raw magnesite:—

	Typical Raw Grecian	Mantudi (a)	Mantudi (b)	Macedon	Kymi
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Magnesium carbonate	95·70	98·08	97·45	94·10 to 98·70	92·05
Calcium carbonate ..	2·20	0·80	1·39	Trace ,, 3·00	6·15
Silica	1·48	0·30	0·20	0·16 ,, 4·00	1·30
Ferric oxide and alumina	0·60	1·20	1·15	0·02 ,, 0·40	0·50

The kilns used in Greece are large gas-fired bottle kilns, and up to a few years ago these were all of the Schmatolla type. In recent years various improvements, including Morgan gas generators, and pressure and exhaust fans, have been introduced, the result being to increase the rate of calcination and reduce the consumption of fuel. Experiments have been made with a rotary kiln of the Fellner and Ziegler type, but this kiln has not hitherto met with great success.

Three kinds of magnesia are produced in the Grecian kilns, viz.: "caustic," "hard-burnt," and "dead-burnt." Hard-

burnt is over-burnt caustic, but it is specially produced in some cases and finds a use in the manufacture of magnesia bricks. The following analyses show the chemical composition of typical samples of these different kinds of magnesia obtained by calcination:—

	Caustic	Hard-burnt	Dead-burnt
	Per cent.	Per cent.	Per cent.
Magnesia	91·00	90·67	90·62
Lime	2·50	3·90	4·10
Ferric oxide and alumina ..	2 85	1·46	1·57
Silica	2·55	2·67	3 00
Moisture	1·10	1·30	0·71

The production of caustic magnesia requires on the average 4·8 cwts. of coal per ton of caustic magnesia produced, whilst in the old type of bottle kiln dead-burning or sintering requires from 6 to 7 cwts. per ton of sintered magnesia produced. The latest type of sintering kiln requires about 4·6 cwts. of coal per ton of sintered magnesia produced.

The Anglo-Greek Company use imported coal in their kilns, but they are making experiments with brown coal, which they are mining locally. The brown coal of Eubœa is stated to be of good quality. The Société Financière de Grèce are mining this Eubœan brown coal at Koumi, and using it in their kilns for the calcination of magnesite. According to the Grecian *Tableaux Statistiques* for 1916, this company raised 63,900 tons of brown coal at Koumi during 1916.

United States.

The magnesite mined in the United States before the war was entirely of the compact type, and California was responsible for practically the whole of the production, which showed no striking growth up to 1914. The mines have produced continuously since 1891, but the output for 1913 was only 8,741 metric tons valued at $77,056. The output has increased largely during the war period, and reached 159,974 short tons valued at $1,393,693 in 1916, and, with the exception of 715 tons produced in Washington, all this was Californian.

The magnesite deposits of California occur partly on the western side of the Sierra Nevada in the Tulare and Kern counties. They occur also at many localities in the serpentine belt of the Coast Range extending from the southern margin

of Mendocino County to Winchester in Riverside County. The more important of the deposits that have been worked up to the present are those of the Tulare, Sonoma, Santa Clara and Kern Counties.

With the exception of a rather singular but very interesting deposit at Bissell, in Kern County, the whole of the compact magnesite deposits of California hitherto described are of the normal type, and occur as veins in serpentine rocks. Many of the Californian deposits are at present too far removed from transport facilities to permit of exploitation, but the potential resources, as set forth in the detailed descriptions given by F. L. Hess[1] and H. S. Gale[2] appear to be large.

It is estimated by the Geological Survey authorities that about one-half of the United States output in 1916 was produced by Tulare County alone, chiefly from the deposits of the Porterville district.

The Porterville deposits include many veins, some of which are of large size. One of these is described by Hess as attaining a thickness of 8 feet, and as having been exploited over a distance of 785 feet of the outcrop, the actual extent of which appeared to be much greater. The magnesite is white, but contains films of serpentine when crushed. Films of red iron oxide and thin coatings of quartz are also to be observed. The following is an analysis by A. J. Peters of a sample collected by Hess:—

	Per cent.
Magnesia (MgO)	45·17
Lime (CaO)	1·32
Silica (SiO_2)	2·28
Alumina (Al_2O_3)	0·03
Ferric oxide (Fe_2O_3)	0·26
Carbon dioxide (CO_2)... ...	50·74

The company working the Porterville magnesite has in the past used the calcined product chiefly in the manufacture of wood pulp at its Oregon mills.

Another important deposit in this region on the western side of the Sierra Nevada, and one presenting some features of special interest, both as regards its nature and mode of occurrence, is that occurring at Bissell in Kern County. Gale[3] describes this interesting deposit as one of sedimentary origin. The magnesite is white, compact in texture, and shows a conchoidal fracture. It disintegrates when exposed to the rain in a manner suggestive of the slacking of lime. It occurs in

1 "The Magnesite Deposits of California," *Bulletin No.* 355 *United States Geol. Surv.*, 1908.

2 "Late Developments of Magnesite Deposits in California and Nevada, *Bulletin No.* 540, *United States Geological Survey*, 1914.

3 Op. cit.

the form of seams interstratified with seams of clay and shale. The following is a section seen as Bissel, showing the interstratification of layers of clay and magnesite:—

	Thickness in inches.
Cherty layer	6
Carbonaceous clay	4
White magnesite	5
Grey clay	3
White magnesite	6
Dark grey clay	4
White magnesite	4
White clay	8
White magnesite	18
Brown clay	4
White magnesite	12
Greenish clay	3
White magnesite	10
Clay (a considerable body) ...	—

The section thus shows a thickness of about $4\frac{1}{2}$ feet of magnesite in a total thickness of about $6\frac{1}{2}$ feet of alternating seams of magnesite and clay. According to L. A. Palmer,[1] the Bissell magnesite beds are usually covered by a seam of magnesian clay, which, though thin, detracts materially from the quality of the magnesite.

Gale quotes the following incomplete analyses of Bissell magnesite by J. G. Fairchild, and points out that, excepting in analysis No. 1, the amount of carbon dioxide is insufficient to form normal magnesium carbonate with all the magnesia present. The analyses suggest that this may be due to the presence of some form of magnesium silicate, perhaps sepiolite; but the presence of hydromagnesite has also been suggested as affording an explanation of this deficiency of carbon-doxide. No. 4 was a selected piece of the purest magnesite obtainable:

	1	2	3	4
	Per cent.	Per cent.	Per cent.	Per cent.
Magnesia (MgO)	37·19	38·32	42·78	44 20
Lime (CaO)	4 25	3·36	1·56	Trace
Silica (SiO_2)	9·64	8·51	6 03	4·75
Ferric oxide (Fe_2O_3) ...	2 46	2·94	1·40	0·76
Alumina (Al_2O_3) .				
Carbon dioxide (CO_2)	40 70	40·12	45·78	47·32

According to L. A. Palmer[2] most of the magnesite obtained at Bissell has been extracted from beds in which the seams

1 *Eng. and Min. Jour.*, **102**, 965, 1916.

2 Op. cit.

of magnesite vary in thickness from 2 to 18 inches, the average thickness being about 4 inches. In mining operations six or seven parts of waste are produced for every part of magnesite obtained. The magnesite is graded according to quality. It is not saleable it if contains more than 11 per cent. of silica and 3 per cent. of lime after calcination. The magnesite is calcined at Los Angeles.

The occurrences of compact vein magnesite, along the Coast Range serpentine belt already referred to, are very numerous, but they closely resemble one another and have much in common with the Porterville occurrence already mentioned.

Important deposits have been described as occurring in the Mendocino, Sonoma, Napa, Santa Clara, Alameda, Stanislaus, San Benito and River Side Counties along the Coast Range serpentine belt. The following analyses, Nos. 1, 2, and 3, by A. J. Peters, No. 4 by W. B. Hicks, No. 5 by J. G. Fairchild, show the composition of samples from various localities along this belt:—

	1	2	3	4	5
	Creon, Sonoma Co.	Red Slide, Sonoma Co.	Red Mt., Santa Clara Co.	Larious Creek, San Benito Co.	Winchester, Riverside Co.
Silica (SiO_2)	1·60	7·67	0·73	0·81	6·17
Alumina (Al_2O_3) ...	0·25	0·26	0·14	Nil	0·80
Ferric oxide (Fe_2O_3) ...	1·09	0·29	0·21	0·50	
Lime (CaO)	1·04	0·04	0·40	1·04	Trace
Magnesia (MgO) ...	45·20	43·42	46·61	46·67	43·80
Carbon dioxide (CO_2) ...	50·43	48·08	51·52	50·60	45·02

A number of these deposits have been and are being worked, notably those of the Sonoma, Napa and Santa Clara Counties, but their total output is small in comparison with that of the deposits worked in the Tulare and Kern Counties further east. Some of the deposits are large, however, and will doubtless figure prominently in the production when the development of transport facilities gives them a chance. As an example of such a deposit, that occurring in the serpentine of Larious Creek in San Benito County may be instanced. According to Gale the chief vein of magnesite at this locality appears to be thick and extensive; it is exposed as a large ledge 500 feet in length and covers 2·6 acres. Analysis No. 4 in the five analyses quoted above represents the average of twelve samples taken from this deposit.

I am indebted to the Director of the United States Geological Survey for two typical specimens of California magnesite, and for analyses of samples taken from the bunker or stock pile represented by these two specimens. One of the specimens is from the White Rock mine in Napa County. The magnesite of this mine contains rather more iron oxide than is usually present in the Californian mineral, and is used in making magnesia bricks. The other specimen is from Porterville and is typical of most Californian magnesite. The following are the analyses:—

	White Rock Mine, Pope Valley, Napa County. Per cent.	Typical Porterville Magnesite. Per cent.
Silica (SiO_2)	2·43	0·80
Ferrous oxide (FeO) ...	2·40	0·20
Lime (CaO)	1·57	1·02
Magnesia (MgO)	43·62	45·94
Carbon dioxide (CO_2) ...	50·11	51·30
	100·13	99·26

Compact magnesite occurs in Nevada and some other States, but has not hitherto been exploited sucessfully outside California.

India.

The magnesite deposits that have been worked in India, chiefly in the "Chalk hills" of the Salem district of the Madras Presidency, and to a comparatively small extent in Mysore, are of the cryptocrystalline vein type. The total production of magnesite in India during 1916 was 17,640 tons, of which 17,540 tons was raised in the Salem district and only 100 tons in Mysore.

The deposits of the Chalk hills were described in 1862 by W. King and R. Bruce Foote in their account of the geology of the Salem district,[1] and later by C. S. Middlemiss.[2] These hills are situated some four or five miles to the north and north-west of the town of Salem, in Southern India. The Madras railway runs within a mile or so of the deposits, but the distance from the port is unfortunately long (it is some 200 miles from Madras and about the same distance from Beypur).

The "Chalk hills" received their name from the chalk-like appearance of the veins of magnesite, which stand out boldly and make a conspicuous feature on their bare surfaces. According to Middlemiss, the hills comprise two areas of about $1\frac{1}{4}$ and $3\frac{1}{2}$ square miles. The rock of the hills consists of serpentinized peridotite (olivine rock); this altered peridotite is intrusive in

1 *Mem. Geol. Surv. India*, **4**, 312, 1864.

2 *Rec. Geol. Surv. India*, **29**, 31, 1896.

gneisses, which occupy the surrounding plain. The serpentine is veined irregularly with magnesite. Middlemiss estimated that magnesite constituted from a third to a half of the total volume of the rock over an area of 620,000 square yards, and about about a tenth to a sixth over an area of 5,536,000 square yards. The richest portions of the deposits seen at the surface form hillocks rising to various heights, up to 140 feet above the plain, so that an almost unlimited supply is available by means of quarrying.

Messrs. King and Bruce Foote report the presence of films and thin veins of fibrous serpentine, chalcedony and quartz in the mass of the magnesite. At and near Namkul (Namcul) along the high road to Trichinopoly from Salem, they observed the presence of what they call "magnesian kunkar," which presumably resembles the material occurring in Mysore (see analysis given below). Other minerals referred to by Messrs. King and Bruce Foote as occurring in the deposits of the Chalk hills are chromite and talc.

These geologists held the view that the magnesites of the Salem area owed their origin to the action of hot water, steam, and carbon dioxide on the enclosing rocks. In support of this view they describe a deposit at Eashermullay, 19 miles E.S.E. of Salem bridge, where magnesite veins traverse a mass of steatite which is invaded by a basaltic intrusion. The Mysore Geological Survey adopts this view to account for the origin of the veins of compact magnesite veins in Mysore. Sir Thomas Holland[1] holds much the same view. He thinks that the formation of the magnesite took place during a late phase of eruption, that it was due to the direct action of hot carbonic acid of eruptive origin on the fresh peridotite intrusion, and that serpentinization took place as an independent process subsequently to the formation of the magnesite.

In a paper on the magnesite industry of India, H. H. Dains[2] quotes the following analyses by Pattinson (No. 1) of a cargo sample of Salem magnesite; and also one by Blount (No. 2), presumably of a selected specimen:—

	No. 1. Cargo sample. Per cent.	No. 2. Selected specimen. Per cent.
Magnesia (MgO)	46·28	47·35
Lime (CaO)	0·78	nil
Ferric oxide (Fe_2O_3) ... / Alumina (Al_2O_3)	0·14	0·30
Silica (SiO_2)	1·17	0·22
Carbon dioxide (CO_2) ...	50·10	51·44
Combined water (H_2O) ...	1·30	0·27
	99·77	99·58

1 *Mem. Geol. Surv. India*, **30**, 136, 1901.

2 *Jour. Soc. Chem. Ind.*, **28**, 503, 1909.

Dains includes in his paper the following analyses of samples of caustic and dead-burnt magnesia obtained from Salem magnesite:—

	Caustic. Per cent.	Dead-burnt. Per cent.
Magnesia (MgO)	96·10	93·12
Lime (CaO)	1·03	1·04
Ferric oxide (Fe_2O_3) ...) Alumina (Al_2O_3) ... ...)	0·44	1·22
Silica (SiO_2)	0·54	4·38
Loss on ignition	2·31	0·34

According to B. H. Brough[1] and E. Kilburn Scott[2] experiments made on a considerable scale with Salem magnesite in the electric furnace yielded a hard dense product of high refractory quality, which is suitable for the manufacture of bricks. Moreover, when powdered, and mixed with some adhesive material, it yields a paste and mortar which can be used for the protection of the brick walls of furnaces. Brough also points out that in an electric furnace, magnesia, unlike lime, does not form a carbide with carbon.

The mining and burning of Salem magnesite has been dealt with recently in a paper by C. H. V. Burlton.[3] He states that the quarry faces are "40 feet sheer," and that the proportion of the magnesite taken out in development may be about 15 per cent. of the "deads," which are removed on tram lines to dumps. The magnesite is hand-dressed and stacked. The lumps of magnesite obtained by quarrying vary in size from pieces known as "lump," which are double the size of a man's fist, down to pieces the size of an apple or walnut, which are known as "smalls." "Lump-crude," to which 30 per cent. of "smalls" may be added, can be used for calcination in kilns. Smalls are in demand for chemical uses.

The magnesite is railed to Madras, partly in a crude and partly in a lightly calcined (caustic) condition. It takes 24 hours to pass the magnesite through the kilns and 2 hours through the zone of greatest heat, which is reckoned to range from 700° to 900° C., and does not exceed 1,000° C. The caustic magnesite is ground so that less than 3 per cent. remains on a 120-mesh sieve. To produce one ton of lightly calcined magnesia from 2·2 tons of crude magnesite requires from 0·2 to 0·3 of a ton of coal.

No dead-burning has been done at Salem since the experiments which were made some years ago, and which were

1 *Jour. Soc. Arts*, **52**, 156, 1904.
2 *Trans. Faraday Soc.*, **1**, 289, 1905.
3 *Jour. East Indian Assoc.*, **8**, 1, 1917.

qualitatively but not commercially successful. In these experiments about 60 tons of magnesite was dead-burnt at a temperature of 1,700° C., but this temperature proved too high for the furnace, though it should be pointed out that in these experiments the magnesia bricks used in the furnace were merely hand-moulded.

According to Dr. W. F. Smeeth and P. Sampat Iyengar,[1] the only deposits of importance among the various occurrences known in the Mysore and Hassan districts of Mysore State are those at Dod Kanya and Dod Katur, which are situated between Mysore and Nanjangud. These are vein deposits of the normal type, in serpentine. At Dod Kanya a patch of serpentine in the Dharwar schists occupies an area about three-quarters of a mile long and a quarter of a mile wide. The serpentine is traversed by veins of magnesite which vary in thickness up to several feet. The veins tend to be either horizontal or vertical, and several of the larger masses are horizontal or but slightly inclined. It is estimated that a considerable proportion of the serpentine mass would yield about a ton of magnesite for every 10 tons of rock excavated, and that the total amount of workable magnesite would amount to several hundred thousand tons.

The magnesite of Mysore is sometimes rendered impure at and near the surface by admixture with *kankar* (nodular calcium carbonate). This impurity disappears a few feet below the surface. Other impurities which require to be separated from the magnesite in mining operations are serpentine, amphibolite (hornblende rock), and chalcedonic silica. When freed as far as possible from these impurities the magnesite is of good quality.

The following analyses quoted from the bulletin referred to above show the composition of magnesite from the Dod Kanya deposit in the Mysore district:—

	Impure surface samples		Large sample from stacks	Clean magnesite from different depths			
				3 feet	6 feet	9 feet	12 feet
Magnesia (MgO) ...	32·48	40·88	43 52	46 49	45·25	45·84	47·12
Lime (CaO)	16·29	6·56	1·24	0·45	0·48	0·52	0·35
Ferric oxide (Fe_2O_3) } Alumina (Al_2O_3) }	0 56	0·57	1 88	0 07	0·12	0·12	0·12
Silica (SiO_2)... ...	2·44	—	5·64	—	—	—	—
Insoluble residue ...	—	2·82	—	1·78	3·60	2·72	0·75

1 "Mineral Resources of Mysore," General Series, Bull. No. 7, *Dept. of Mines and Geology, Mysore State*, 1916.

On the basis of prospecting work carried out at Dod Kanya, it has been estimated that the probable cost of mining and sorting the magnesite will be from 3 to 5 rupees per ton of magnesite, exclusive of supervision.

The results of an investigation of the suitability of Mysore magnesite for making dead-burnt magnesia indicated that the best procedure was to grind the magnesite with a small quantity of iron oxide to induce fritting, and thus confer upon it in some measure the features possessed by Austrian dead-burnt magnesia.

Australia.

Magnesite of the compact type occurs in many different parts of Australia, and at some localities there are deposits of considerable size. The more important of these deposits are those of Fifield in New South Wales, Heathcote in Victoria, and Tumby Bay in South Australia, all of which have yielded supplies of magnesite in recent years. Promising deposits are reported to occur also in Queensland and in Western Australia.

New South Wales.—The magnesite occurring about $3\frac{1}{2}$ miles north-west of Fifield in New South Wales shows at the surface as large rounded blocks piercing a bed of red clay, and is exposed in this manner over an area of about 100 acres.[1] The magnesite is white and very pure. An analysis by Mingaye gave the following result:—

	Per cent.
Magnesium carbonte	99·01
Lime	absent
Ferric oxide and alumina ...	0·54
Silica	0·42

The deposit at Fifield appears to be of considerable extent. According to Jaquet the cost of loading into drays at the time he wrote was 1/- to 1/6 per ton. Fifield is 350 miles from Sydney, and 11 miles from the Bogan Gate—Bulbodney line.

According to the New South Wales Mines Department Report for 1916, the total output of magnesite in New South Wales for that year was 3,761 tons, and of this total Fifield produced 3,516 tons. 200 tons were produced at Attunga and 45 tons at McIntyre.

Victoria.—Magnesite has been raised in small quantities in recent years at Heathcote in Victoria. The total production of the mineral in this state up to the end of 1914 was only 510 tons valued at £1,578. The Heathcote deposits yielded 189 tons valued at £3 per ton in 1915.

1 *Ann. Rept. Dept. Mines, New South Wales*, for the year 1907, p. 75.

The magnesite at Heathcote occurs superficially as nodules and veins near the junction of a basic serpentinous rock with granite. The veins occur in the granite as well as in the serpentinous rock. The latter is much decomposed at the surface, and it appears to be the result of this decomposition under weathering influences that the magnesite has been formed, probably somewhat after the same style as at Fifield in New South Wales.[1]

Queensland.—Magnesite veins in serpentine rocks are reported to occur at many localities in Queensland, but mostly in deposits of small extent. In a recent report on these occurrences B. Dunstan[2] states that the deposits about Marlborough and Kunwarara, between Rockhampton and St. Lawrence, are extensive. At Princhester Creek, in this district of Central Queensland, hundreds of tons of magnesite are exposed at the surface. Outcrops of magnesite are numerous at various other localities in the same district. Deposits of pure magnesite which appear to be of considerable extent occur at Mt. Pring, 12 miles from the port of Bowen. The following are analyses of some of these Queensland magnesites:—

	Mt. Pring	Kunwarara		Princhester
		(a)	(b)	
	Per cent.	Per cent.	Per cent.	Per cent.
Magnesia (MgO)	46·00	43·40	46·80	46·90
Lime (CaO)	1·18	0·10	Trace	1·50
Ferric oxide (Fe_2O_3) } Alumina (Al_2O_3) ... }	Nil	1·50	0·50	0·20
Silica (SiO_2)	0·90	8 00	2 00	0·20
Carbon dioxide (CO_2) ...	51 72	46 70	50·30	51·30

South Australia.—The magnesite deposits worked near Tumby Bay in South Australia have been described recently by L. K. Ward.[3] They are situated in the hundred of Stokes, about five miles from the town of Tumby in Eyre Peninsula. Deposits of talc occur in the same district, which is occupied by ancient metamorphic rocks.

The magnesite occurs in the form of veins, which are irregularly spaced over an area of 21 × 1½ chains. The veins vary in thickness up to 4½ feet, and a few of them appear to extend continuously for a length of 40 feet. Hæmatite veins run parallel to those of the magnesite, and the magnesite is in

1 *Rec. Geol. Surv. Victoria* 4, 52, 1917.

2 *Queens. Govt. Min. Jour.*, 17, 529, 1916.
Rev. of Min. Oper. S. Austr., No. 20, 30, 1914.

part stained superficially with iron oxide. White specimens of the weathered magnesite are scattered over the surface of the deposit, and one of the specimens was found to contain 99·38 per cent. of magnesium carbonate. Three samples from three different trenches, representing material of average quality to be obtained by hand-picking, were analysed by W. S. Chapman and gave the following results:—

	No. 1 Trench	No. 2 Trench	No. 3 Trench
	Per cent	Per cent.	Per cent.
Magnesia (MgO)	41·83	46·23	43·01
Carbon dioxide (CO_2) ...	46·86	50·99	47·46
Lime (CaO)	1 08	0 24	0·32
Ferrous oxide (FeO) ...	0·14	0·20	0·19
Ferric oxide (Fe_2O_3) ...	0·96	0·20	0 46
Alumina (Al_2O_3)	2·03	0 57	2·13
Silica (SiO_2) ...	5·56	1 00	5·12
Sodium chloride (NaCl) ...	0·28	0·11	0·18
Water at 100° C.	0·30	0·16	0·26
Water above 100° C. ...	0·94	0·20	0·34
Totals	99·98	99·90	99·47

A further reference to the magnesite deposits of the Tumby Bay district appeared more recently in the *Rev. Min. Oper. S. Austr.*, No. 24, 1916, in which it was stated that 100 tons of magnesite was at the time of writing awaiting shipment from Tumby Bay jetty to Port Pirie.

Western Australia.—In Western Australia, magnesite has long been known to occur at Bulong, in the north-east Coolgardie goldfield, and this occurrence has been described recently by F. R. Feldtmann.[1] Bulong is about 19½ miles east of Kalgoorlie. The rocks of the locality are described as a greenstone complex; they consist chiefly of serpentine and gabbro, with occasional masses of talcose rock.

The magnesite occurs as veins in the serpentine, which is usually much decomposed in the vicinity of the veins. The veins in some places are closely crowded. The main area occupied by magnesite outcrops is over two miles in length, and the total area covered by the magnesite-bearing serpentine in this area alone is over 300 acres. Another area to the north of this occupies 80 acres, and there are others.

1 *Rept. Dept. Mines, Western Australia*, for the year 1915, p. 131.

Trial pits down to a depth of 12 feet from the surface showed veins of magnesite up to 2 feet thick. No estimate could be formed as to the amount of material available, but it seems clear that a large tonnage of magnesite containing over 90 per cent. of magnesium carbonate could be obtained.

South Africa.

Compact magnesite is found in deposits of considerable size in the Barberton district, Eastern Transvaal, at various localities near the railway line between the stations of Kaapmuiden and Malelane.[1] Kaapmuiden is about 87 miles from Delagoa Bay, and 300 miles from Johannesburg.

The magnesite occurs as veins in a belt of serpentine which is associated with the schists of the Swaziland System.

Hall describes the magnesite as occurring in countless thin white veins traversing the mottled serpentine in all directions. The veins vary in thickness from three to four feet down to mere films, but veins from two to six inches thick are by far the most common. They show a very irregular distribution in the serpentine and change their disposition from the horizontal to vertical within a few yards. The thicker veins (two to four feet thick) are as a rule highly inclined.

The rock is perfectly white. It is rather soft as a rule and yields much dust when broken; but some masses are hard and can be handled without producing dust. The magnesite usually contains patches and specks of serpentine, and lumps of coarsely crystalline dolomite are stated to be occasionally present. It is further characterized by a somewhat cellular texture, and there is a considerable amount of quartz present, lining the walls of the small cavities and impregnating the mass of the magnesite. Thin films of silica occur frequently between the magnesite veins and the enclosing serpentine.

The following is an analysis of a comparatively pure picked specimen of the magnesite, of specific gravity 2·95 :—

	Per cent.
Magnesia (MgO)	45·27
Carbon dioxide (CO_2)... ...	49·80
Silica (SiO_2)	2·30
Ferric oxide (Fe_2O_3)	0·80
Moisture (110° C.) (H_2O) ...	0·16

From an examination of samples of Kaapmuiden magnesite one gets the impression that on the average the percentage of silica is considerable, and well above the amount indicated in

1 "The Magnesite Deposits of Malelane," by A L. Hall: *Transvaal Mines Dept., Rept. of the Geol. Surv. for* 1906, p. 127.

this analysis. A recently quoted analysis of a representative sample shows 5·24 per cent. of silica. Specimens of compact magnesite showing a considerable amount of silica in the form of vugs and impregnations are no doubt obtainable from any locality where extensive deposits of such ancient magnesite occur, but this seems to be the case in a much larger measure with the Kaapmuiden material than with Salem magnesite.

Compact magnesite of the vein type occurs at various other localities in the Transvaal, notably in the Olifants River area in the north-west portion of the Lydenburg district and adjoining part of the Pietersburg district. The veins vary up to $3\frac{1}{2}$ feet in thickness, but the magnesite is in part calcareous. P. A. Wagner[1] states that a fairly representative sample from Jachtlust contained 93·4 per cent. of magnesium carbonate and 2·25 per cent. silica. The nearest point on the railway to Jachtlust is Pietersburg, 51 miles distant.

Other deposits of compact magnesite in South Africa are described as occurring in the Marico district, Transvaal, and the Enkeldoorn district, Rhodesia. A sample of this Rhodesian magnesite examined at the Imperial Institute some years ago consisted of fairly typical cryptocrystalline magnesite, but contained layers of brown fibrous serpentine. It gave the following analysis:—

	Per cent.
Magnesia	45·90
Lime	nil
Ferric oxide and alumina ...	0·55
Insoluble matter	3·04
Loss on ignition	50·20

Various other occurrences associated with the Great Dyke of Southern Rhodesia, at Belingwe, Lomagundi and other localities, are mentioned in a recent report by A. E. V. Zealley, who refers to the belt of country occupied by this dyke as the most promising in Rhodesia for workable deposits of magnesite.[2]

Italy.

In Italy compact magnesite occurs and is or has been quarried at Castiglioncello, at Monterufoli and also on the island of Elba, all in the Firenze mining district,[3] which includes the provinces of Pisa and Livorno. It is also mined to a small extent in the province of Turin.

In Elba the magnesite is quarried in a primitive manner on the slope of Mt. Capanne in the commune of Campo, where

1 *South African Journal of Industries*, 1, 576, 1918.

2 *Rhodesia Munitions and Resources Committee Report*, 1918, p. 16.

3 *Rivista del Servizio Minerario nel* 1915. See also account by G. D'Achiardi in *Rassegna Mineraria*, 41, 93, 1914.

it occurs in altered serpentine. The mineral is dug from small holes in the ground, and the holes are abandoned at a depth of a few metres. The magnesite is of the "baudisserite" variety; it is white, friable, rich in silica, and becomes pasty when wetted. According to analyses given by G. D'Achiardi[1] it contains from 41 to 42 per cent. magnesia, about 44 of carbon dioxide, 1 to 3½ of lime, 8 to 9 of silica, and 3 to 4 per cent. of water. The output has been irregular. The recent production has been at the rate of 600 tons a year, and the magnesite is sold at about £1 12s. per ton, for use in pottery manufacture.

The Castiglioncello deposits are in the commune of Rosignano Marittimo, on the hills between the Salvetti-Vada and Livorna-Vada railways, and within a mile of the latter. They consist of large veins in serpentine and occur near the contact of the latter with Eocene beds. Three veins running for a length of a kilometre are exposed, and vary in thickness from 3 to 10 metres. Large quarries were opened up in 1914-15 and kilns for calcining the magnesite have been erected recently. Local transportation to the kiln is by light railway and rope-line. The deposits are large, and, though the output during 1915 was only from 3,000 to 4,000 tons, it is estimated that a daily output of 100 tons can be maintained.

The Castiglioncello magnesite is partly hard and compact, and partly friable. Its composition when dressed is approximately as follows:—

	Per cent.
Magnesium carbonate	89
Calcium carbonate	5
Ferric oxide	2
Silica	3

Magnesia bricks are made from the calcined product at Vada, by a firm which previous to the war used material imported from Greece and Austria.

The deposit at Monterufoli in the province of Pisa is a vein ranging from four to eight metres in thickness. It is found along with serpentine and occurs near the contact of this with Eocene beds, which include chalk. The magnesite is associated with quartz and chalcedony, which are removed as far as possible by hand-dressing. A sample of the dressed raw magnesite gave the following analysis:—

	Per cent.
Magnesium carbonate... ...	86·02
Calcium carbonate	9·60
Iron oxide and alumina ...	2·63
Insoluble	1·07

1 *Atti (Mem.) Soc. Toscana Sci. Nat.*, **20**, 86, 1904.

The dressed raw magnesite is carted about 2½ kilometres to the station at Monterufoli. From there it is taken by rail to Ardenza, and thence by cart to Montenero (Livorno), where it is calcined in a Dietzsch furnace.

Other localities.

Of other localities where compact magnesite is known to occur in considerable quantities mention may be made of the Bridge River and Cassiar Districts of British Columbia; the island of Margarita near the northern coast of Venezuela; the island of Santa Margarita in Magdalene Bay, Lower California (Mexico), and the island of Cedros further north; Frankenstein in Silesia; Kraubat in Austria; the Chalkidean peninsula in Macedonia; the Paphos district in Cyprus; Eski-Chehir in the province of Brusa, Asia Minor; Kraljevo and other localities in Serbia; and the area between Koumac and Voh in New Caledonia. None of these deposits has hitherto figured conspicuously in the production of magnesite, though in some cases the possibilities appear to be considerable. For some years there has been a steady but small output at Santander in Spain.

The Bridge River (British Columbia) deposits have been reported on recently by C. W. Drysdale, who describes an outcrop 52 feet wide and 48 feet long near the south-west end of Liza Lake. The locality is some 30 miles from the Pacific Great Eastern Railway at Bridge River Crossing on Seton Lake, but it is considered unlikely that the deposit could be profitably worked at present.[1]

The United States imported 81 short tons of magnesite from Mexico in 1912.

The chief deposits in the island of Margarita, Venezuela, are reported to be about a mile from the port of Porlamar, and three miles from the port of Pambatar, both of which have good shipping facilities. American companies were reported to be working at these deposits in 1912, and 508 short tons were imported by the United States from Venezuela during 1915. They are reported to have been worked again during 1917, producing 10 tons per day, but shipping facilities were poor, and freight charges to New York were $19½ per ton.

The available raw magnesite in the Eski-Chehir deposit, Asia Minor, was recently estimated at 300,000 tons, and the deposits are stated to be near the railway.

Deposits of white compact magnesite of the usual type have long been known to occur in the serpentine of Cyprus, and the magnesite is of good quality, but the deposits are

[1] *Summary Rept. Geol. Surv. Canada*, 1916, p. 48.

reported to be of only small extent. There was an output of 15 tons from the Akamas mine in the Paphos district during 1916.

Occurrences of magnesite are stated to be abundant in the district of New Caledonia referred to above, and an analysis quoted by M. Glasser[2] indicates that the mineral is of fairly good quality, but shows 3·3 per cent. of lime. The conditions of occurrence in New Caledonia are promising, but hitherto there has been no considerable production. A trial shipment of 42 tons was reported in 1907.

Hydromagnesite

Hydromagnesite is a hydrated basic carbonate of magnesium, the formula of which is generally given as $3MgCO_3.Mg(OH)_2.3H_2O$. It usually occurs in white chalk-like masses, not much unlike some forms of magnesite in appearance, but rather soft and easily powdered. The mineral sometimes occurs as thin crystalline encrustations, and occasionally assumes a globular form. When crystalline it consists of small monoclinic prisms. Its low specific gravity (about 2·1) and the fact that it gives off water copiously when heated in a test tube afford a ready means of distinction from anhydrous magnesite.

Hydromagnesite occurs as an alteration product of other magnesium minerals at many localities, but usually only in such small amounts as to be of no economic significance. A few interesting occurrences in Canada, Ceylon and the United States are described below.

Canada.

Of the various Canadian occurrences of hydromagnesite the most important at the present time appear to be those near Atlin in British Columbia, which have been examined and described recently by G. A. Young.[2] The deposits are situated close to Atlin; one of the two chief groups of deposits is only about half a mile from Atlin wharf, the other is on the south-east border of the town site.

The hydromagnesite is pure white, rather soft, and falls to powder on drying. Some of it is very wet in the natural state and may lose as much as 22 per cent. of water at 105° C., but most of it appears to be fairly dry, except for chemically combined water. Where saturated with water the deposits are so situated as to facilitate ready drainage. The mineral is

1 *Ann. des Mines*, 5, 548, 1904.

2 *Summary Rept. Geol. Surv. Canada*, 1915.

exposed at the surface and can be won by open quarrying without the removal of any overburden.

The largest deposit in the first group already referred to (about half a mile from Atlin wharf) covers about 18 acres, and appears to have an average thickness of 2 ft. 8 in. The deposit was sampled in two pits at different depths. One of these pits was in the south-eastern portion of the deposit at a point where the total depth was 2 ft. 2 in., the other was in the northern part of the body at a point where the thickness was 3 ft. 6 in. The following analyses of samples collected in these two pits were made on material dried at 105° C., at which temperature the loss of water varied from 1·31 to 2·64 per cent.

	South-eastern Pit			Northern Pit		
	Depth 3″ Per cent.	Depth 1′ 1″ Per cent.	Depth 1′ 11″ Per cent.	Depth 4″ Per cent.	Depth 1′ 4½″ Per cent.	Depth 2′ 4″ Per cent.
Silica (SiO_2) ...	1·86	0 90	0·54	1·22	1·96	9·22
Alumina (Al_2O_3 ...	0·67	0·10	0·17	0.67	0·14	0 94
Ferric oxide (Fe_2O_3)	0·15	0·09	0·11	0·18	0·45	0·73
Ferrous oxide (FeO)	0 60	0·45	0·64	0·63	0·65	0·78
Lime (CaO) ...	2 04	0·82	0 68	1·26	1·50	6·44
Magnesia (MgO) ...	41·13	42·35	42·19	40·56	41·93	35·23
Carbon dioxide (CO_2)	35·98	36·10	36·17	35·96	36·04	37·70
Water (H_2O) ...	18·02	18·95	19·05	19 04	17·66	8·20
Totals ..	100 45	99 76	99·55	99·52	100·33	99·24

The second group of deposits (that on the south-east border of the town site) consists of three large bodies of hydromagnesite that lie in shallow valleys depressed 30 to 75 feet below the surrounding country. The mineral in this group of deposits is much wetter than that of the first group, and analyses show losses of water up to 21·77 per cent. at 105° C. The largest of the three deposits varies in thickness from 1 ft. to 5 ft., with an average of 3 ft. Two samples from different parts of this deposit lost respectively 1·21 to 1·18 per cent. of water at 105° C., and gave the following results on further analysis:—

	1	2
	Per cent.	Per cent.
Silica (SiO_2)	0·74	3·48
Alumina (Al_2O_3)	0 35	2·85
Ferric oxide (Fe_2O_3)	0·15	0·56
Ferrous oxide (FeO)	0·66	0·81
Lime (CaO)	0·32	0·42
Magnesia (MgO)	42 85	38·94
Carbon dioxide (CO_2)	36·35	34·31
Water (H_2O)	19·10	19·10
Totals ..	100·52	99·47

It is estimated that the two groups of deposits contain approximately 180,000 tons of hydromagnesite in beds ranging from about 1 ft. to 5 ft. in thickness. It is reported that about 200 tons of the material was shipped to San Francisco in 1904 and that some was sent to England. During 1915 a trial shipment of some 500 tons was sent to Vancouver. The district is stated to be easily accessible by way of the White Pass and Yukon Railway from Skagway, Alaska, to Carcross, Yukon Territory, and thence by a bi-weekly boat service on Tagish and Atlin Lakes.

Another locality in British Columbia where according to G. C. Hoffmann[1] hydromagnesite occurs in considerable abundance is that near the 180-mile house on the Cariboo Road, 93 miles north of Ashcroft, in Lillooet district. At this locality there are three or four deposits from fifty to a hundred feet across, standing a foot or more above the level of the surrounding surface, and the hydromagnesite is traceable from one to the other of these deposits over an area of some fifty acres of ground. A shaft sunk in one of these deposits passed successively through about 5 feet of the pure white material, a layer of about 6 inches of the same of a somewhat yellowish colour, a layer of some 3 feet of the pure white material, a layer of about 18 inches of the yellowish coloured material, an apparently thin layer of the pure white material, and finally reached what evidently constituted the bed of the deposit, viz.: a dark-coloured mud containing a few well-preserved shells. On another of these deposits a shaft is stated to have been carried to a depth of 30 feet without the bottom being reached.

The material examined consisted of a pure white, somewhat compacted, yet readily friable aggregate of fine crystalline

1 *Ann. Rept. Geol. Surv. of Canada, new series*, vol. 11, p. 10 R., 1898.

particles with a few intermingled rootlets. An analysis by R. A. A. Johnston gave:—

	Per cent
Magnesia (MgO)	43·71
Lime (CaO)	0·10
Carbon dioxide (CO_2)	37·03
Alumina (Al_2O_3)	0·02
Ferric oxide (Fe_2O_3)	0·04
Phosphorus pentoxide (P_2O_5)	0·30
Soluble silica	0·38
Insoluble, chiefly silica	1·53
Water with a little organic matter ...	17·79

An analysis of the insoluble portion showed that of the 1·53 per cent., 1·35 consisted of silica and 0·10 of alumina.

It is thought that the origin of these deposits is connected with the occurrence of the later Tertiary volcanic rocks, basalts, etc., which are abundant in the area referred to.

An occurrence of hydromagnesite is reported as having been found by J. M. Bell in the form of white encrusting masses, in part showing a globular structure, in cavities of a porous and highly weathered dolomite on the south shore of Dease Bay, some 30 miles S.W. of Fort Confidence, Great Bear Lake, Mackenzie District, North-West Territory.[1]

Ceylon.

Hydromagnesite has been reported by the late James Parsons in connection with the work of the Ceylon Mineral Survey, as occurring in the nitre cave at Padiyapelella, in the Central Province, Ceylon. This material had been previously described by Dr. John Davy in "An Account of the Interior of Ceylon" (London, 1821), as magnesite, and had been used locally as a sort of whitewash, for which purpose it was sold in small quantities at one rupee per pound.

The formation of the cave is due partly to solution action, and partly to quarrying, in a band of crystalline "limestone," which is presumably a metamorphosed dolomite. The hydromagnesite has probably been formed by the decomposition of the metamorphosed dolomite, on which, and on the associated gneisses and other metamorphic rocks, it occurs as encrusting matter, partly in nodular form. These Ceylon dolomites frequently contain forsterite (an olivine) and other magnesium silicates formed by thermal metamorphism. The forsterite readily hydrates to serpentine and through the action of carbon-dioxide solutions suffers further decomposition. The formation of the magnesium carbonate is probably due in part if not

1 *Geol. Surv. Canada*, N.S. **12**, 22 *R*.

altogether to the action of carbon-dioxide solutions on the forsterite and serpentine in the dolomite.

An analysis of a sample of the material by Davy showed 86 per cent. of magnesium carbonate, 9 of silica, 5 of water, and only a trace of lime. A sample analysed at the Imperial Institute showed 33·3 per cent. of magnesia and 16·04 per cent. of lime, and seemed to indicate that the material probably consisted of a mixture, including perhaps magnesite, and calcite or dolomite, as well as hydromagnesite.

United States.

An interesting occurrence of hydromagnesite is reported by H. S. Gale in the forks of Larious Creek, San Benito Co., California.[1] Larious Creek has already been mentioned as a locality at which there occurs a large vein deposit of compact magnesite in serpentine. The hydromagnesite in this locality forms a white deposit of limy appearance on a weathered surface of sheared serpentine. Associated with this weathered crust there are small globular masses of hydromagnesite, and the following is an analysis of a picked specimen of these from the white powdery material on the weathered surface:—

	Per cent.
Magnesia	40·60
Lime	0·34
Silica	2·50
Alumina	0·13
Ferric oxide	0·44
Carbon dioxide	34·89
Undetermined	20·10
Loss on ignition	54·10

Comparison of Magnesite Types as Raw Materials for Refractories.

In considering the relative merits of the different types of magnesite as raw materials for refractory uses, we may perhaps rule out hydromagnesite as comparatively unimportant, or couple it with compact magnesite, and distinguish three types, viz.: (1) breunnerite, which is spathic and ferriferous; (2) non-ferriferous spathic magnesite, which may be to a considerable extent dolomitic and therefore calcareous; and (3) compact magnesite, which is typically neither ferriferous nor calcareous to any considerable extent.

1 *Bull.* 540 *U.S. Geol. Surv.*, 1914.

In comparing these different types, the advantage due to coarseness of texture should be mentioned, especially in the case of breunnerite. In a spathic magnesite or breunnerite of coarse texture, any admixture of dolomite impurity is likely to be less intimate than it is when the texture is fine, and the fragments obtained by coarse crushing are therefore likely to be purer. Moreover, as already mentioned, breunnerite blackens when calcined, and for this reason can be more easily cleaned from impurities by hand-picking, whilst it can also be dressed magnetically to exclude dolomite, and in this way the quality of the sinter can be controlled.

A further advantage possessed by breunnerite is that ferrous carbonate loses its carbon-dioxide at a rather lower temperature than does magnesium carbonate; but it seems unlikely that the comparatively small percentage of ferrous carbonate present in breunnerite as used for sinter-production, can on this account alone confer the great advantage in effective sintering and kiln-economy that has been claimed for breunnerite, as compared with compact magnesite. There are, however, other factors to be considered, and the settlement of this question appears to call for investigation.

Perhaps the formation of magnetic iron oxide by calcination increases the thermal conductivity of the mass very substantially, and if so the sinter yielded by breunnerite should attain the temperature of the kiln more quickly and more uniformly than should the purer magnesia yielded by non-ferriferous magnesite. Another factor that should perhaps be considered is the oxidation of the ferrous oxide, whether in the formation of magnetic oxide or in the further reaction to form magnesioferrite. The effect due to any disseminated granules of pyrite and other impurities that may be present should also be taken into account.

What the relative importance of these different factors may be it would perhaps be difficult to say; but it seems clear that, in the sintering of breunnerite, we have fairly definite physical and chemical changes of a not very mysterious character, and that these changes afford an explanation of the kiln-economy that is claimed for the sintering of breunnerite as compared with compact magnesite. We may sum up these changes briefly as follows:—(1) The effect of the cleavages in giving the kiln gases access to all parts of the mass; (2) the formation of magnetic oxide of iron, which involves oxidation and which perhaps increases the thermal conductivity of the mass; (3) the segregation of the iron oxide through its combination with the magnesia in the last stage of sintering to form magnesioferrite, which at the end of the operation is scattered in the form of

microscopic granules through a matrix of crystalline magnesia (periclase).

If we accept this explanation of the sintering process in the case of breunnerite we are led to infer that the sintering or dead-burning of compact magnesite of the Grecian or Salem type should not present any extraordinary difficulty, though it may involve a slightly greater expense in fuel and more resourceful kiln management. Practice in these matters is, of course, much more important than theorizing. The fact seems clear, however, that the end-product (periclase) of sintering in the case of breunnerite is essentially the same as for compact magnesite; and it seems easier to admit that the actual temperatures of transformation from amorphous to crystalline magnesia are the same in the two cases, than to admit that they are widely different.

We can quite easily understand why the expulsion of carbon dioxide and the operation of sintering should be effected somewhat more economically with breunnerite than with compact magnesite; but the disadvantage suffered by the latter in this respect does not appear to be one that resourceful kiln-construction and kiln management cannot overcome. It is therefore interesting to note that, as already indicated, the Anglo-Greek Magnesite Company appears to have made substantial progress in this direction.

More serious, perhaps, from the refractory standpoint is the frequency with which quartz and serpentine abound as impurities in compact magnesite and dolomite in saccharoidal magnesite, and the difficulty of eliminating these impurities so as to obtain a product of such steady quality as that which can be obtained by dressing breunnerite.

Even if that difficulty could be overcome, however, there remains the larger economic questions as to the costs of production and transport, and proximity to fuel supplies. In all these respects the advantages enjoyed by the Austrian industry are very substantial, and however pleasing it may be to know that we are not dependent upon the Austrian supplies, there can be little doubt that the restoration of normal conditions will make competition with the Austrian industry a difficult matter, so far as the production of cheap and useful magnesia sinter is concerned.

The manufacture of bricks is of course a rather different question. The value of bricks, which is comparatively very high, depends for the most part on the cost of manufacture, and from this point of view our manufacturers doubtless regard sinter as raw material. Perhaps it would be as well, with the high freight-costs now ruling, to adopt this view more seriously,

and apply it to Greek and Salem magnesite also, for it would seem to be much more economical to import sinter than to import raw magnesite. Another reason for doing this is that it should be possible to standardize the sinter more economically at the place where the magnesite is mined.

Economics and Statistics.

Under this heading it will be convenient to deal briefly with such production and other statistics as are available for the countries chiefly concerned in the magnesite industry, and to indicate the more important factors in the economic situation.

The outputs of magnesite since 1911 in the countries chiefly responsible for the world's production has been as follows:—

World's Output of Magnesite (in Metric tons).[1]

	1911	1912	1913	1914	1915	1916
Austria-Hungary ..	147,481	171,206	200,947	—	—	—
Greece	86,956	106,338	118,054	136,701	159,981	199,484
United States ..	8,505	9,539	8,741	10,248	27,676	140,630
Italy	360	400	600	740	9,200	18,252
Spain	1,400	1,480	958	583	1,400	2,500
Canada	827	1,555	467	325	13,411	50,284
India	3,547	15,630	16,462	1,708	7,572	17,928
Australia	321	6,008	7,220	2,056	1,647	4,084
Union of South Africa	319	546	403	519	569	553

The above production table shows that, in pre-war years, Canada, India, the United States and Italy were unimportant producers compared with Austria-Hungary and Greece. The large increase in the outputs of the former countries during the war is due to the cessation of oversea exports from Austria-Hungary. The combined outputs of raw magnesite in Greece, the United States, Italy and the British Empire has grown from 131,810 metric tons in 1913 to 435,752 metric tons in 1916. It may be noted that this combined output of crude magnesite in the countries mentioned during 1916 is only about equivalent to the raw magnesite represented by the Austro-Hungarian exports of sinter during 1913.

The dominant factors in the pre-war situation as regards magnesite were: (1) the cheapness of production and transport of the Grecian product, which on account of its purity was used

1 The production figures here given are for raw magnesite, except for Austria-Hungary, the figures for which represent exports of sintered magnesia. The table is not complete. Some other countries in which production has taken place, including Norway, Venezuela and Mexico, are not included.

chiefly in the caustic form; and (2) the good quality and cheapness of the Austro-Hungarian product, which consisted of sintered magnesia eminently suited for use as a refractory.

Austria-Hungary.

The position of Austria-Hungary is that she produces refractory magnesia enormously in excess of her requirements, and her magnesite mining industry depends on exports. In the absence of figures showing her consumption we may note that Austria-Hungary's iron output is very small compared with that of Germany, and we shall not go far wrong if we estimate her refractory-magnesia requirements accordingly. On this assumption, Austria-Hungary's consumption of refractory magnesia in a normal pre-war year must have amounted to but a very small percentage of her total output.

The figures for total exports from Austria-Hungary may therefore be assumed to be not far below those of total production, and a comparison of these figures with the United States imports of calcined magnesite (see below) shows clearly that the growth of the Austro-Hungarian magnesite industry has depended largely on the increasing demand for refractory magnesia in the Eastern United States, where it is used extensively in the steel- and copper-smelting industries. The fact that the United States leads so easily in both copper and iron production amply explains this large consumption of refractory magnesia, as well as the keen interest that American firms have shown in the development of the Austrian industry.

The normal pre-war distribution of Austro-Hungarian exports of sintered magnesia may be judged from the following table showing the chief countries to which the exports were consigned in the year 1913:—

Exports of Sintered Magnesia from Austria-Hungary.

Consigned to	1913	
	Metric tons	Percentage
United States..	113,300	56
Great Britain	34,400	17
Germany	27,662	14½
France	14,697	7
Other Countries	10,888	5½
Total	200,947	—
Total value	£544,321	—

The amount of Austro-Hungarian sintered magnesia actually consumed in the United States, however, was substantially in excess of the figure here given, for some supplies were received through other countries. Taking the four-year period ending June 30th, 1913, the total imports of calcined magnesia entered for consumption in the United States were 486,588 metric tons, and of this total 460,946 metric tons or 95 per cent. were entered as direct imports from Austria-Hungary. These direct imports by the United States from Austria-Hungary for the period referred to constituted about two-thirds of the latter's total exports of sintered magnesia. Moreover, the exports of calcined magnesia from the United States during this period were entirely to Canada, and totalled only 5,384 metric tons, or about 1 per cent. of the total imports.

Sintered magnesia as entered in the world's production and other tables given above does not include magnesia bricks. These are not enumerated separately in the official statistics of Austria-Hungary, but are included with Dinas, bauxite, and graphite-bricks. The following table shows the chief countries to which these bricks were exported in the year 1913:—

Exports of Dinas, Magnesia, Bauxite and Graphite Bricks from Austria-Hungary in 1913.

Consigned to	Metric tons
Germany	11,374
Russia	4,735
Great Britain	2,686
Italy	2,588
France	1,720
Other Countries	2,961
Total	26,064
Total value	£149,323

The Veitsch Co. is reported to have produced 53,271 tons of sinter in the year ending June 30th, 1916, as compared with 44,910 tons in the year ending June 30th, 1915; and by increasing the price of the product it had been able to maintain its prosperity.

Greece.

Greece, like Austria-Hungary, produces magnesite for export; but whereas Austro-Hungarian exports consist wholly of the sintered product, those of Greece are largely raw magnesite. The following table shows something of the normal distribution of the Greek exports in pre-war days:—

EXPORTS OF GREEK MAGNESITE [1]

	Metric tons		
	1910	1911	1912
United Kingdom ..	7,754	12,098	13,732
Germany	16,632	24,259	35,613
Rest of Europe	6,538	12,259	12,633
America	7,200	8,685	10,594
Totals	38,124	57,301	72,572

This table shows that nearly 50 per cent. of the total tonnage of Greek exports of magnesite and magnesia went to Germany, where it was used largely in building construction. When allowance is made for the fact that the chief part of the exports to Germany consisted of caustic magnesia, one ton of which represents at least two tons of raw magnesite, whereas the exports to England and America were mostly of raw magnesite, it is clear that Germany took a disproportionately large share of the Greek output. Germany's total exports of "magnesite" in the three years referred to were 5,399, 4,496, and 7,132 metric tons respectively.

The total output of "calcined magnesite" in Greece during 1916 was 29,932½ metric tons compared with 27,248 in 1915. Of these totals 8,606½ tons were dead-burnt in 1916 compared with 4,118 tons in 1915.

According to J. Hogg,[2] Greece might be expected to maintain her 1912 output for a period of 15 years from that date. It would appear, therefore, that the favourably situated magnesite deposits of Eubœa now being worked have not a long life of large production before them, so far as can be judged from the reserves known to Hogg at the time when he wrote. Allowance

1 Including raw, calcined and dead-burnt. The total outputs of dead-burnt magnesia for these three years were only 4,072, 6,422, and 5,408 metric tons respectively, and were consumed in roughly equal amounts by Europe and America.

2 *Trans. Inst. Mech. Eng.*, 46, 128, 1913.

must be made for the possibility of working less-favourably situated deposits in Eubœa; but the output to be maintained is large, and if Hogg's estimate is anywhere near the truth it provides a feature of large significance, for the exhaustion of the Greek mines would undoubtedly have a very important effect on the economic situation.

The superior transport facilities enjoyed by Eubœan magnesite have given it a great advantage, and have made it a controlling influence in the world's markets. Greek magnesite could be landed at eastern American ports in pre-war days at an inclusive cost less than that of the charge for freight alone across the United States, and so long as this condition prevails Californian magnesite will not be able to compete with Grecian in the eastern States in normal times. Facility for shipment has enabled Greek magnesite to maintain its hold on European markets also, and will probably continue to do so until the growth of underground mining expenses, or increasing transport cost, or approaching exhaustion, turn the scale against it.

United States.

As shown by the output table given above the United States was a comparatively small producer of magnesite in pre-war days, and the output, which was entirely Californian, was wholly or chiefly consumed in the west, largely for the purpose of paper manufacture. The eastern States depended almost entirely on imports from Europe, and, as we have seen already, these were drawn chiefly from Austria-Hungary; but quite apart from the Austrian magnesia sinter required by the steel- and copper-smelting trades, the eastern States imported large amounts of crude Grecian, and the imports of crude magnesite alone exceeded the total production of the United States.

The large importance of the United States as a consumer of magnesite may be gathered from the following table of imports, compiled from the United States official statistics:—

Imports of Magnesite into United States
(Entered for consumption, year ending June 30th).

	1912	1913	1914	1915	1916	1917
Crude (short tons)..	14,708	16,827	10,795	18,732	50,796	89,646
Calcined (ditto) ..	102,499	172,661	144,495	62,947	16,186	4,724
Crude (value in dols)	88,482	111,276	46,611	80,625	281,620	748,951
Calcined (ditto) ..	990,241	1,731,443	1,485,273	751,766	282,768	182,037

IMPORTS OF EASTERN COMPARED WITH WESTERN PORTS
(For year ending June 30th, 1912).

	Eastern Ports	Western Ports
Crude (short tons)	14,289	418
Calcined (ditto)	102,377[1]	563

[1] Including 261 short tons to Northern Border districts.

IMPORTS OF CALCINED MAGNESITE INTO UNITED STATES
(In short tons; year ending June 30th).

Ports of Entry	1912	1913	1914	1915	1916	1917
New York	3,028	8,418	6,221	10,856	3,490	782
Philadelphia	76,171	119,682	113,806	37,153	10,148	1,792
Michigan	—	—	—	64	382	497
St. Lawrence	—	—	—	693	1,882	1,651
New Orleans	22,805	43,568	23,258	11,115	—	2
Other Ports	935	923	1,462	3,467	284	—
Totals	102,939	172,591	144,747	63,348	16,186	4,724

IMPORTS OF CALCINED MAGNESITE INTO UNITED STATES
(In short tons; year ending June 30th).

Consigned from	1912	1913	1914	1915	1916	1917
Austria-Hungary ..	99,104	163,715	134,260	52,086	—	—
Greece	114	1,604	3,232	4,437	11,413	1,792
Netherlands	2,410	4,508	4,190	3,554	1,950	—
Germany	689	2,412	2,578	722	12	—
United Kingdom ..	62	1	13	280	349	784
Canada	234	350	404	948	2,440	2,148
Other Countries ..	[1]327	—	69	[2]1,321	22	—
Totals	102,940	172,590	144,746	63,348	16,186	4,724

[1] Chiefly Norway, Mexico and British India.

[2] Chiefly Italy and Venezuela.

EXPORTS OF CALCINED MAGNESITE FROM UNITED STATES
(Year ending June 30th).

	1912	1913	1914	1915	1916	1917
To Canada (short tons) ..	864	1,761	2,920	1,141	[1]38	—
To Newfoundland and Labrador (short tons) ..	—	—	560	—	—	—
Total value in dollars	15,218	37,465	55,867	21,154	1,183	—

The United States experienced a shortage of magnesite supplies during 1915 and 1916, due to the shutting off of imports from Austria; but this loss has been made good by the large increase in home production, together with increased imports from Canada and Greece. The large increase in home production is due chiefly to the remarkably rapid development of the spathic-magnesite deposits in the State of Washington, but there has also been a large increase in the output of Californian compact magnesite.

UNITED STATES OUTPUT OF MAGNESITE (by States).
(Short tons).

State	1915	1916	1917
California	30,499	154,259	211,663
Washington	—	715	105,175

R. W. Stone of the United States Geological Survey, reports that the production of magnesite in the United States for the six months ended June 30th, 1918, was 93,700 short tons, of which total California produced rather more and Washington State rather less than 50 per cent. This rate of output is much lower than that for 1917, in which year the total production for the two states reached 316,838 short tons. The falling off in the output is attributed to increased cost of transport and a large increase in the imports of Canadian magnesia, which can be landed in the Eastern United States at a cheaper rate than the magnesia of California.

Italy.

In pre-war days, Italy produced only a comparatively insignificant amount of magnesite from her deposits in Turin

[1] Including 3½ tons to Peru.

and Elba. Since the war there have been important developments in the province of Pisa, notably of the deposits at Castiglioncello, which are near the coast. These deposits are within easy reach of railway and shipment facilities, and appear therefore to be of prospective importance to other countries, though it will be noted from the analyses quoted already that Pisa magnesite contains an appreciable percentage of lime. The following figures show how comparatively unimportant as producers of magnesite the provinces of Torina and Livorno have become since production commenced in Pisa :—

Output of Magnesite in Italy (by Provinces).
(Metric tons).

Province	1913	1914	1915	1916
Torino	600	740	2,300	1,260
Livorno	—	—	600	600
Pisa	—	—	6,300	16,392
Totals	600	740	9,200	18,252

Canada.

In addition to the deposits near Calumet in Quebec, which have recently shown a large output, Canada has many other deposits, but these have not hitherto been exploited in any large way, presumably on account of their unfavourable situations. The British Columbia compact magnesite and hydromagnesite, like the Californian magnesite, are more likely to be consumed in the west than in the east in normal times should their development be taken up.

The proximity of the spathic-magnesite deposits of Quebec to the eastern American markets should give them an advantage over the deposits of Washington State in normal times, especially if, as claimed, the rather high lime percentage of the Quebec magnesite proves to be non-detrimental, or if some means can be found to reduce it.

According to a recent report by T. C. Denis (*Can. Min. Inst. Bull.*, Jan., 1918) the chief feature of the Quebec magnesite industry in 1917 was the introduction of rotary kilns for dead-burning magnesite at Montreal and Hull. The magnesite is ground to pass a 20-mesh screen, mixed with 5 per cent. of ground iron ore and sintered at a temperature of 2,400° F. The product is stated to be a very desirable refractory, worth $50 per ton

Although, however, the possibilities of this and other Canadian deposits are considerable, and it seems not unlikely that Canada will be able to export, as well as to supply her own needs, there will be vigorous competition when normal conditions return.

According to the *Report on Mining Operations in the Province of Quebec* during 1917, the magnesite marketed by Quebec operators in that year totalled 58,340 tons. This includes some calcined and sintered magnesia. The total tonnage in terms of crude magnesite is estimated at about 64,000 tons. The Steel Company of Canada has experimented largely with Quebec magnesite in their open-hearth furnaces, and claim that, by suitable treatment, it yields results as good as those obtained by using Austrian magnesite. Good results are also obtained by using a mixture of sinter, caustic magnesia and magnesium chloride as a plaster on the walls of the steel furnaces.

India.

The production of magnesite in India, as shown in the output statistics given above, has increased substantially during the war, and the output at Salem for 1917 reached about 20,000 tons. Excepting the Mysore contributions of 2,212 tons in 1913, 1,281 tons in 1914, and 100 tons in 1916, the whole of the Indian output has been obtained from the Salem deposits. The Tata Co., of Bombay, consume a portion of the Indian production, but most of it is exported.

According to C. H. Burlton[1] there is no sintering done at Salem. A large amount of the magnesite is lightly calcined at a temperature not exceeding 1,000 C., to produce caustic magnesia, and this is partly used for refractory purposes, which of course necessitates re-burning at a higher temperature to yield a sintered product. Such a procedure is obviously on the whole uneconomical. So also is the export of the magnesite in a raw state, however tempting this may be on grounds of convenience, for over 50 per cent. of the freight in this case is useless from the refractory point of view. It therefore seems desirable, assuming that Salem magnesite is to be used for refractory purposes, that the exports for these purposes should consist of sintered magnesia of good quality. In this connection it should be pointed out that it cannot be seriously less economical to export sinter than it is to export caustic magnesia, at least so far as conditions of production are concerned.

Against this consideration, of course, we have to put the fact that when normal conditions return Salem may be unable

1 "The Magnesite Mines of India," *Jour. East India Assoc.*, 8, 1. 1917.

to compete with other sources of supply in the production of sintered magnesia, and the further fact that caustic magnesia for building purposes is more valuable than sintered magnesia in normal times. Unless, therefore, a favourable market for Indian sintered magnesia can be guaranteed, it would be unreasonable to expect the owners to instal sintering kilns.

The magnesite industry at Salem is at a disadvantage compared with the Styrian, inasmuch as it has to import its fuel. The Mysore deposits are handicapped in the same way. Dr. W. F. Smeeth's recent report on the probable cost of burning Mysore magnesite in electrically heated kilns, though inconclusive, is not reassuring. He anticipates that it would require 15 cwt. of Bengal coal, costing at least Rs. 16, to produce one ton of sintered magnesite, and he estimates that the total cost of the electrical power required to do the same work would be about Rs. 50.[2]

If, however, this estimate by Smeeth is compared with the actual expenditure of fuel in the sintering of Greek magnesite (see above), it will be seen to be excessive. The Mysore deposits suffer from the further disadvantage that they are of comparatively small dimensions and therefore do not appear to promise much. On the other hand the large dimensions of the Salem deposits, the good quality of the magnesite, the cheap labour available, and the low mining costs generally, seem to indicate that these deposits have a promising future before them.

Australia

The production of magnesite by States in Australia since 1911 has been as follows:—

(Long tons).

	1911	1912	1913	1914	1915	1916
New South Wales ..	150	5,700	7,000	2,000	830	3,761
Victoria	166	211	104	23	189	30
South Australia.. ..	—	—	—	—	—	130
Western Australia ..	—	—	—	—	602	97
Totals	316	5,911	7,104	2,023	1,621	4,018

The New South Wales production has been mostly from Fifield, which is 325 miles to the west of Sydney; but the 1916

[1] *Rec. Dept. Mines and Geology, Mysore State*, **15**, 11, 158, 1916.

output included 200 tons from Attunga and 45 tons from McIntyre. According to the Ann. Rept. Dept. Mines for New South Wales for 1916 the magnesite production of the state for that year was used mostly by the Broken Hill Proprietary Co., at their Newcastle works. The New South Wales output for 1917 is reported to be about 9,190 tons, and of this 5,000 tons was raised at Attunga. It was recently reported that the Broken Hill Co. was prospecting the Mt. Pring deposits, near Bowen in Queensland, with a view to obtain larger supplies for their steel-smelting plant at Newcastle.

The Victorian output has been mostly, if not wholly, from Heathcote, the South Australian from Tumby Bay, and the Western Australian from Bulong, E Coolgardie.

All the magnesite hitherto described and produced in Australia appears to be of the compact variety. Australia has probably sufficient of this magnesite to suffice for home requirements, but so far as can be judged from known deposits she is not likely to become a considerable exporter.

South Africa.

The Union of South Africa has probably sufficient magnesite to meet its needs in the Transvaal deposits. When the Malelane-Kaapmuiden deposits were first opened up some years ago it was expected that they would be developed largely, but a glance at the output figures given above shows that these expectations have not been realized. Up to the present there has been no considerable export from South Africa, and so far as can be judged from the deposits hitherto described it does not seem likely that there will be under normal conditions, as these deposits appear to be of rather small dimensions and the Kaapmuiden magnesite is in parts very siliceous. There was an export of about 80 tons of crude magnesite from the Barberton district to the United States in 1915, but this was due to the temporary shortage of supplies and the exceptionally high price then offered in the United States.

The compact magnesite deposits of the Lydenburg district are not favourably situated; nor are those of Rhodesia, and it seems unlikely that the deposits hitherto described will be developed, except for local requirements.

According to P. A. Wagner (*op. cit.*) only the Pettygrew's Nek deposit, about two miles S.S.W. of Kaapmuiden, is being quarried at present in South Africa. The average monthly output from this deposit during 1917 was about 65 tons. The magnesite is sold f.o.r. at Kaapmuiden station at £2 12s. 6d. per ton, and the output is taken almost entirely by a Johannesburg firm for the manufacture of liquid carbon dioxide, which

is used throughout South Africa for aerating water. The calcined magnesia is sold locally, and is taken mostly by the Union Steel Corporation of Vereeniging, who re-calcine it and use the sintered product in the manufacture of magnesia bricks. To do this they first briquette the caustic magnesia and dead-burn the briquettes. The sintered briquettes are then crushed, and the product thus obtained is made into bricks, which are burned in special kilns.

Prospects.

The prices of raw magnesite and calcined magnesia in New York during 1914 were as follows:—Grecian crude, $7 to $8; Grecian caustic (fine-ground in paper-lined barrels), $25 to $35; Austrian sinter (crushed or fine-ground) $16¼. The normal f.o.b. cost of raw Grecian magnesite since the war is stated to have been about 27 francs per ton, whilst that of caustic hard-burnt, and dead-burnt, in bags, is given as about 125 francs per ton. According to a recent *United States Commerce Report*, one mining company in Greece has stated that its prices before the war were $4 per ton for raw magnesite f.o.b. port of lading, whilst in March, 1917, it could easily obtain $7.50 per ton. The *Tableaux Statistiques du Mouvement Minier de la Grèce* during 1916 indicates that values of magnesite sold by the larger companies in Greece averaged from about 41½ francs per ton for Mantudi to 46½ francs for Limni magnesite, due presumably to the large demand in the United States. The average value given for dead-burnt magnesia during that year is about 151 francs per ton for Limni and 218 francs per ton for Mantudi. In the *Chemical Trades Journal*, London, for July 11th, 1914, calcined magnesite is quoted at £5 15s. per ton f.o.b. makers' works or usual ports, whilst on July 5th, 1918, the price was £14 per ton. On July 12th, 1918, the price quoted was £16 per ton, and on the 19th of the same month calcined magnesite had risen to £35 per ton.

The notable feature of these prices is the high cost of Grecian caustic compared with Austrian sintered magnesia in pre-war days, presumably owing to the large demand for white caustic magnesia for cement-making and other purposes. It is well that this fact, and the further fact that Austrian sinter can be exported at such a cheap rate in normal times, should be kept in view in any attempt we may make to deal with the prospects in magnesite production.

Bricks made in the United Kingdom from imported Greek and Indian magnesite are likely to cost more than those made from Austrian sinter under normal conditions.

Whether in view of the costliness of magnesia bricks as compared with sinter, it may be economically feasible to continue the manufacture of bricks made from Grecian or Salem magnesite is a point worth discussing. Freights would be economized as already mentioned, by the importation of refined sinter in place of crude magnesite; but makers in this country may not find it profitable to continue the production of bricks from Salem or Grecian or other such sinter after the war except for special uses. It seems clear that the costs of such supplies would substantially exceed those of Austrian sinter, and the fact that neither Greece nor India finds it worth while to export sinter in a large way can scarcely be regarded as a promising feature. It rather looks as if producers of the raw material are waiting expectantly under the impression that the return of normal conditions will permit the Austrian exports to dominate the refractory magnesia market in the future as they have done in the past.

The economic advantages that favour the Austrian export trade have already been mentioned. One of the most important of these advantages is the open-cast working of large deposits of breunnerite, the nature of which permits of the production of standard qualities of sinter at cheap rates. It would perhaps be unreasonable to expect that sintered magnesia should be produced at such a cheap rate under the less favourable mining conditions prevailing in Greece, Italy, India and California. What then are the prospects as regards competition from other large spathic magnesite deposits which are more fairly comparable with those of Austria-Hungary?

The two deposits that have come into prominence during the war as large producers of spathic magnesite for refractory uses are those of Quebec and the State of Washington in North America. The deposits in both these areas are extensive, and their potentialities as producers are amply indicated by their very rapid development during the last two or three years to meet the demands arising from war conditions.

In both these cases, however, the refractory magnesia produced is much more expensive than the sinter of Austria-Hungary. The Quebec product contains more lime than is desirable; but according to a report in the Canadian Mining Institute Bulletin for January, 1918, the Quebec sinter was then selling at the rate of $50 per ton, which is rather more than three times the price at which Austrian sinter sold in the New York market during 1914. Even assuming, therefore, that it may be found possible to produce from the Grenville deposits a sinter as low in lime as desirable, there remains the

question whether it can be produced at a sufficiently cheap rate to compete with the Austrian.

The spathic magnesite now being produced from the deposits recently opened up in the State of Washington is of good quality, but even assuming that this quality can be maintained, the large freight charge this magnesite has to face in getting to the eastern markets will prove a serious handicap to the companies mining these deposits when normal conditions return. The prices quoted free on rail at Valley and Chewelah in Washington State during 1917 were $\$7\frac{1}{2}$ per ton for crude and $\$32\frac{1}{2}$ per ton calcined. Adding freight charges to this rate for calcined gives a total cost in the Eastern States comparable with or exceeding that of Canadian.

Judged by comparison with the exceptionally high costs of ocean freights now ruling, these land-freight costs are not heavy, but time will readjust this order of things, and again bring into relief low costs and efficiency of production as factors in the economic situation. It is to be hoped that, meantime, producers of magnesia bricks in Britain and other parts of the Empire will have taken full advantage of the period of absolute protection that war conditions have afforded them, and will have succeeded in establishing the industry on a firm basis.

Magnesite occurrences remind us how precious are those wasting assets of the earth, its useful mineral deposits, on the exploitation of which intensive civilization depends for its maintenance. This is especially true of the composite type of magnesite, which previous to the war was wanted chiefly for use in making oxychloride cement, and is still wanted very much for the same purpose, to say nothing of its growing importance as an ore of magnesium.

Mr. Hogg has told us that the Grecian deposits cannot be expected to persist to any considerable depth, and, as already pointed out, he estimates that Eubœa has only a few years to run as a large producer of cheap magnesite. His experience as regards the shallow depth of this type of magnesite is in agreement with that of mining engineers elsewhere; and in the opinion of the present writer it is also in agreement with the best explanation that can be given of the origin of compact magnesite, viz.: that it has been formed at comparatively shallow depths by the action of carbonic acid in solutions of subærial origin.

It is otherwise with the deposits of spathic magnesite and breunnerite, which owe their origin to metamorphism at greater depth; and, if we take a large view of the world's economy, it is to those deposits that the smelting industries should look

in the future, as they have done in the past, for the large supplies of refractory magnesia they require, leaving most of the compact magnesite to those who need it for cement-making, magnesium-alloy production, and other uses in which the chemical purity of the raw material is more essential than it is in the refractory magnesia required for the ordinary purposes of metallurgy.

It seems indeed almost inevitable that future readjustments will be along these lines; but whether so or otherwise, the present position is such as to show clearly the need there is for a vigorous investigation of magnesite resources. There are no doubt many deposits waiting to be found and developed. Italy furnishes a good example in the development of her large deposits at Castiglioncello, which have only recently come into prominence.

The compact type of magnesite, however, is a conspicuous object at the surface, and falls a ready prey to the prospector. The spathic type is not so easily discerned, and calls for closer vigilance. On that account we may perhaps reasonably expect good practical results to follow from an investigation of crystalline dolomites in metamorphic areas; and it may be suggested to those geologists who have the opportunity of making such field investigations, that by giving attention to this matter they may at the same time be able to shed more light on one of the most fascinating problems in rock-genetics, viz.: the origin of spathic magnesite and breunnerite.

DISCUSSION.

Mr. WILLIAM DONALD:—Mr. President, Ladies and Gentlemen, I have felt greatly honoured by being asked to head this discussion, and shall endeavour to present as briefly as possible my personal views on some of the subjects raised.

In the first place I think The Ceramic Society have been most fortunate in getting Mr. Crook to collect the very great volume of information that has been put before us. It is a magnificent piece of work, by one who has an almost universal outlook on the subject; and it is all the more valuable to all concerned than otherwise that Mr. Crook should have had this regard for his subject and that he has dealt with it with a perfectly open mind. In his presentation of the main conclusions he had come to, Mr. Crook took us away from local concerns and we had a voyage to other continents, and I think we were fortunate in having this personal address, rather than a series of quotations from written matter.

In the paper itself we have statements about the productions and the consumptions of the various countries interested, and if there is the opportunity to make these more complete and up-to-date I hope that will be done. So far as these matters are concerned I don't think criticism is possible. We have here a compendium of all the knowledge we shall require to form opinions about the future of our industry.

Perhaps Mr. Crook does not appreciate the enormous expansion of the basic steel industry of the world, and the extent to which the Austrian magnesite trade would require to be expanded to cope with that trade. Presuming that during the war the Austrian works had been fully employed keeping the Central Powers supplied with magnesite products, how can it be expected that they have been able to expand their plant and their workings to enable them to cope with the demands of the enormously expanded basic steel industry in all the steel producing countries of the world?

But apart from that question, there is undoubtedly the more important factor of the property of the Austrian magnesite, and the further question whether the old fetish about the standard of that quality is unapproachable by the pure magnesite beds of Greece. Mr. Crook takes the side of the past; but we British makers who have experienced so much during these last four years are in a better position to judge what we can do. It is admitted that the quality of the Austrian standard was very high, and that the possibility of using these bricks over again to such a great extent was a factor greatly in their favour. But I am certain that in the near future our bricks will bear comparison if they do not surpass the Austrian even in these qualities. To a certain extent that must depend on the co-operation of the Greek mines, as mineral products always are dependent for their quality on recognition by the mines of what the manufacturing establishments require.

One advantage that the Austrian makers have is that they are alongside the quarries, who get to know, therefore, not only what is wanted, but if anything is not wanted, the reason for that. The brickworks do the selecting and rejection, and naturally the quarries, knowing these rejections, keep them as low as possible. If we British makers could define any quality that would give better results I am sure the Greek quarries would rise to the occasion, and it is in the hope that my remarks may assist to that that I confine them to the questions about the nature, extent and distribution of the mineral impurities of Greek magnesite, and the effect that they have on the purer particles of the finished bricks.

In Greek magnesite the mineral impurities are largely the hydrated silicates of magnesia: (1) the ferro-magnesian silicates —mainly the chlorites and the serpentines, and (2) the purer silicates of magnesia such as talc. During calcination these irregularly distributed mineral impurities in contact with magnesium and calcium carbonates become very similar to well recognisable oxide minerals, either the orthosilicates, monticellite, forsterite or chrysolite, or the metasilicates—enstatite, bronzite, hypersthene or tremolite. With higher calcination other silicates formed are subsilicates, somewhat similar to humite and sapphirine. The melting point of these impurity minerals deserves serious consideration, as we shall better understand the aggregate produced from our raw materials if we understand each mineral particle composing that aggregate.

When highly sintered the silica, iron and lime react first, and if present in different proportions the alumina quickens or retards that reaction. When being refired in brick form we can quicken or retard the interaction of the silicate impurities present in our magma just as electric steel furnace slags are treated. These require very careful alteration, and any additions to our magnesite bricks require to be as carefully considered. That indicates the real purpose for making further additions, when it is actually proved that the additions made are advantageous. They are not required as bonding materials, but to make the impurities naturally held by the magnesite serve that purpose. They may also be required so as to alter the character of the basic brick from one able to withstand furnace temperatures of 1,900—2,000° C. to basic bricks which are only able to withstand temperatures of 1,650° C., but which have physical properties enabling them to withstand the more physical wear and tear of basic open-hearth furnaces. In the summary of his review Mr. Crook quotes a statement that in Austrian magnesite the lime, alumina and silica are regarded as undesirable ingredients, and that they should not exceed 5 per cent., 2 per cent. and 6 per cent. respectively; also that the ferric oxide should not exceed 11 per cent. These are very wide margins, as the mineral impurities could be present (in average molecular ratios) whose constituents would at high temperatures form compounds easily fusible. In order to govern the molecular ratios of the impurities it is necessary to know the ratio in which it would be best to have these present, both in the ultimate average analysis of the brick and in the various particles themselves. Knowing that we can say what the average analysis of the raw magnesite or the sintered magnesite should be, the Greek mines can approximate to that by dressing the stone more carefully in some quarries or in

some beds when there is excess of mineral impurity that will affect deleteriously the average analysis, than is necessary when that mineral impurity is not present in excess. Some of these impurity minerals have little iron or alumina. Others have them in excess. Each can be recognised, and an average worked to.

I hope to publish at an early date the result of a very exhaustive series of tests to prove what the impurity molecular ratio would be best to have in magnesite bricks. This will at least be able to act as a guide to the Greek quarries about what is required to attain the best results from Greek magnesite. As an indication in the meantime of the alteration of the melting point with difference of percentage of the constituents of fusible minerals, one of the best series I know is that of the ferrous slags that are worked in copper and lead metallurgy, when the main constituents are ferrous oxide and silica, with lime sometimes replacing the ferrous oxide to a greater or less extent. The orthosilicate $2(CaFe)O{\cdot}2SiO_2$, and the sesquisilicate $3(CaFe)O{\cdot}2SiO_2$ have each melting points between 1,100° C. and 1,200° C. if there is no lime present. With 4 per cent. and 8 per cent. of lime replacing the ferrous oxide the lime acts as a flux and the melting point falls. With 12 per cent., 16 per cent., 20 per cent. and so on, up to 44 per cent. of lime replacing the ferrous oxide the melting point rises more or less in a straight line, the lime thus acting as a retarder of the fluxing. If the slag has the bases and the silica present as the bisilicate $(CaFe)O{\cdot}SiO_2$, the lime replacing the ferrous oxide in continually greater proportion first acts as a quickener, then as a retarder, then again as a quickener, and a second time as a retarder of the melting point. Working with these ferrous slags is comparatively simple in comparison with the various ferro-magnesian silicates able to be present in magnesite bricks. In the latter case there are at least five constituents, and one of them you wish to retain as much as possible as pure magnesia or as a highly basic mineral. What is necessary is that when any additions to these mineral impurities of magnesite bricks are to be made the makers should know definitely for what purpose they are made, and the users should be able to appreciate the advantage gained by that addition.

The great advantage of the best of the Austrian bricks is that the lime, alumina and silica, and particularly the alumina and silica, are so low that when these impurities are cooling from the state of incipient fusion definite mineral compounds shiver and freeze out of the melted highly basic compounds, leaving the less basic silicates to shiver and freeze out at perhaps 100° lower. This leaves these lower freezing silicates

very small in proportion to the volume mass of the brick. It also assists in having the particles very similar in micro-structure.

The questions that concern an enquiry into the respective qualities of Greek and Austrian magnesite are: (1) Would there be any advantage and can we actually reproduce the molecular ratios of the impurities in Austrain magnesite by suitable additions to Greek magnesite, or (2) Can we do better with the Greek magnesite presently imported of 85 per cent. magnesia quality with a modification of its silicate impurities? A third question is: (3) To what extent can the quality of the Greek bricks be improved when it is possible for the Greek mines to revert to the 92 per cent. magnesia quality available in the past.

To answer these in their order, we can easily alter the molecular ratios of the iron, lime, alumina and silica in Greek magnesite to those of the Austrian if we add sufficient impurity. Owing to our comparatively high silica content it would take 42 parts of iron and alumina added to 100 parts of Greek magnesite of the quality of the last cargo we received to reproduce the exact molecular ratios of the impurities in the best Austrian bricks, or it would take 30 parts to reproduce the exact molecular ratios present in what I consider as the second quality Austrian.

We can therefore drop the impurity molecular ratio of the Austrian standard.

The answer to the second question is necessarily short, as I don't want to anticipate results. Undoubtedly we can improve the 85 per cent. magnesia quality. With certain additions we can bring about a silicate magma that will distribute itself throughout the 100 cubic inches of the brick when that is being fired in manufacture, and which on the brick cooling will have the lowest freezing point of any of its silicates that melt out raised by about 100° C. But if it is desired to attain temperatures approaching 2,000° C., and if the bricks experiencing that temperature are to sustain a load even of 25 lbs. per square inch, the ends of the bricks exposed to the combustion zone which will contain one-fifth of their bulk of comparatively low-temperature melting silicates will be soon affected by the high temperature.

On the other hand, if the magnesite could be of 90 to 92 per cent. magnesia quality, the advantage would be that, depending on the temperature to be experienced in the furnace, the bricks could be made of higher or lower heat-resisting or metal-resisting quality. It might be said that for the bulk of the bricks such purity is not required; but my point is that

it is not only high magnesia contents that are wanted, but also that the individual impurities can be present in molecular ratios all to be defined, and the raw magnesite should be able to be altered by these additions so as to approximate to the best. That can best be done with magnesite low in each impurity present and especially in silica.

With very high temperature of calcination there is no doubt that any silicates present can be converted into the more basic silicates as they are in contact with magnesia. Enstatite is the most acid metasilicate of magnesia and melts at 1,557° C. Forsterite, the more basic orthosilicate, melts at 1,890° C. The silicate of lime, wollastonite, melts at 1,540° C. Tricalcic aluminate melts at 1,720°, and a less aluminous compound at 1,600° C.

In his recent report about the crushing strain of various qualities under heat Le Chatelier stated that pure Eubœan bricks containing 93 per cent. MgO ruptured at 1,600° C. under a load of 114 lbs. per square inch. At similar temperatures commercial quality French bricks ruptured under 68 lbs. per square inch, and Styrian bricks under a load of 25 lbs. per square inch. These tests were made on $\frac{3}{8}$ inch cubes in a laboratory furnace, and, while not giving results able to be compared with results attained in furnace practice, they are at least directly comparable with one another. Depending on the purity of the material the rupture took place gradually, the less pure bricks and the Austrian bricks acting as if they were plastic matter. It was an Eubœan magnesite brick of 93 per cent. magnesia quality that I referred to in my recent communication to The Ceramic Society as having been received from Mr. Brooke. These Eubœan bricks were moulded under hydraulic pressure.

Where the squatting tendency due to the melting of the silicates is not experienced in furnace practice other factors have to exercise first consideration. It is certainly never experienced in the bottoms of basic steel furnaces beneath the dolomite bath, as the temperature there does not approach 1,600° C., nor is the load so great as that applied in the laboratory test.

Mr. Crook expressed the opinion that British magnesite bricks would again experience severe competition from Austrian bricks in the future, and that the spathic magnesite of Austria would resume the position in the refractories trade that it did in the past. My opinion is that the Greek magnesite will not be displaced by spathic magnesite of Austria if we British makers and the Greek mines work together as far as we can, the makers of the bricks trying to define to the Greek mines

the qualities that the British steelmakers require in their linings of their furnaces. Mr. Crook also stated that the supplies of Greek magnesite in sight raised the question of how long the British market could depend on Greece for supplies; but that statement was based on a report dated 1910, which has been fortunately found to be greatly underestimated, and which does not take into account the deposits in other parts of Greece. Greek magnesite naturally lends itself to many metallurgical operations, and with suitable treatment will, I am confident, in the near future be rendered the best resistant to steel and slags in all basic processes.

Prof. FEARNSIDES congratulated the Society upon having secured a paper which took so broad an outlook over the question of mineral supply as the one which Mr. Crook had communicated. He regarded the paper as an up-to-date compendium of digested information to which scientific workers, makers and users of basic refractories alike, would turn whenever they required a well-balanced view of the conditions which controlled the magnesite industry in 1918.

He supported Mr. Crook's contention, that, as well from the scientific point of view as from the experience of all who have had to handle either the raw carbonate or the manufactured oxide, products made from the Austrian spathic magnesite and Grecian compact or massive magnesite are physically two entirely distinct and essentially different materials. Personally he had little doubt that if makers of basic steel by the open-hearth process, requiring dead-burnt magnesia for use as a container of steel and molten slag, had products made from the Grecian and from the Austrian materials to choose from at prices which were approximately identical, they would on its merits invariably select the Austrian. It is therefore a matter of some importance that the geographical location of Austrian magnesite supplies is favourable to large scale workings, and that from the calciners at the quarries the product can be cheaply rail-borne to not too distant ports. The circumstance that in Austria the spathic magnesite masses have a bulk of many millions of tons, whereas at none of the thousand or more known occurrences of compact vein-magnesite has there ever been discovered any individual mass where even fifty thousand tons of marketable material could be wrought, is also a matter of special importance in this same connection.

Describing the dead-burnt product which the Austrians exported Mr. Crook had commented on the very high temperature at which the sintering was accomplished. In this connection it may be of interest to place on record the fact that

if the spathic export product be heated up rapidly to 1,500° C. and maintained at about that temperature for, say, half-an-hour, the grain size of the individual crystals of periclase (MgO) which compose the aggregate is very considerably increased. From this it is perhaps permissible to argue that in the commercial sintering process no temperature so high as 1,500° C. has ever been attained.

Mr. B. MOORE:—I do not like to pass one conclusion of Prof. Fearnsides. It is one of the commonest experiences in pottery to find that a body fired at a high temperature changes when fired at a low temperature.

Mr. MASON:—I am just a manufacturer of magnesite bricks; I am not a chemist. I agree with Prof. Fearnsides in his remarks about the temperature necessary to calcine Austrian magnesite. If it is necessary to calcine Grecian magnesite to the high temperature as stated this can be done. Reference has been made to the purer Grecian magnesite of 92 per cent. and the inferior quality of about 85 per cent.

It is important that the purest quality should be used and we can then make any necessary additions because we know exactly what we are doing; but if we get the inferior magnesite at 85 per cent. we do not know where we are. The problem is, how to use Grecian material so as to debar the Austrian from coming into this country, and if the users will only back us up I think we shall be able to show them that a good brick from Grecian magnesite can be produced.

Mr. COSMO JOHNS:—I think I had better stand here as a metallurgical engineer.

According to my experience the Styrian brick as a resistant to high temperatures was very ordinary, it was not a special refractory from the standpoint of high temperatures. It would not stand as, say, the best silica brick would. The trend of metallurgical products is towards high temperatures, and the Austrian brick would hardly stand those temperatures, therefore the problem is not how to imitate the Austrian brick. The problem to-day is for the manufacturer to make use of the superior virtues of the Grecian magnesite. I have tried those bricks but they were inferior to silica bricks. I do not think that the line to adopt is to add impurities, but rather to discover some method of manufacture in which the high refractory powers of magnesia will be fully realized.

Dr. A. SCOTT:—In the section dealing with the mineralogy of magnesite and the related carbonates, the isomorphous series

magnesite-siderite is divided up and names applied to mixtures whose composition varies within definite limits. From the mineralogical point of view this is highly inadvisable, as it tends to give the impression that such mixtures approximate to definite chemical compounds. On the other hand, if the sub-division is based on the economic point of view, then the presence of lime compounds ought to be taken into account. In considering magnesite as a raw material for refractories, it is best to regard it from a petrological rather than a mineralogical point of view and, although magnesite can hold very little calcium carbonate in solid solution, the latter is often present in the form of dolomite in "magnesites," and forms a constituent equally as important as the iron. Since up to the present, no satisfactory method of eliminating lime has been devised, it is better, from the point of view of refractories, to classify magnesites on the basis of the lime and iron contents of the rock.

In the section dealing with the comparison of the various types as raw materials more emphasis might be laid on the effect of the non-ferrous impurities. Even in the case of the Austrian material, the crystallization of the periclase is influenced by the presence of silicates fusible at the temperature of dead-burning. While it is true that periclase can be obtained as the end product of the dead-burning of both breunnerite and compact magnesite, the temperature and duration of firing requisite for the production of crystalline magnesia seems to depend to a great extent on the amount of fusible silicates which form.

Mr. T. CROOK:—Mr. Donald has raised a number of interesting questions, some of which are rather beyond the scope of my paper. I agree with him as to the desirability of amplifying the statistical data, and I hope that his plea will reach the notice of the authorities whose duty it is to inform the public on these matters.

With reference to Greek *versus* Austrian magnesite, Mr. Donald says I take the side of the past, and he goes on to make it clear that he attaches more importance to what has happened during the war period, than to the few years preceding this period, as a guide to the prospects. My reply is, that unless the commerce of the future is going to develop on romantic rather than on business-like lines, I think we may reasonably attach a great deal of importance to the conditions that prevailed in the few years before the war, as a guide to what may happen in the near future.

Mr. Donald's remarks about the "enormous expansion" of the basic steel industry seem to me rather vague and misleading, and I fail to see why he should presume that the Austrian works have been fully occupied during the war in keeping the Central Powers supplied with magnesite. Such evidence as I have been able to gather points to the opposite conclusion. The figures for the world's iron and steel production, basic and otherwise, are available for recent years. With these and the figures for magnesite before us, it seems to me a demonstrable error to assume that the world's near-future demand for refractory magnesia will exceed Austria-Hungary's capacity for production to any substantially larger extent than it did before the war.

Now of course I am merely trying to get as close as possible to the facts of the situation. I have neither said nor implied that compact magnesite could not be made into first-class refractory bricks. On the contrary I have in my paper given prominence to the fact that compact magnesite can be made to yield refractory magnesia of finer quality than that yielded by breunnerite. For the ordinary purposes of steel-metallurgy, however, this higher-grade product could not compete with Austrian sinter before the war, and the simple explanation of this seems to be that the consumer takes an all-round efficiency view, and buys that product which, all things considered, serves him best. It is for the British maker of magnesia refractories to produce from the compact magnesite of Greece a refractory which, all things considered, will be at least as profitable to use as Austrian sinter and Austrian bricks.

In all this discussion about Greek *versus* Austrian magnesite for the British market, however, it is perhaps permissible to ask where the British Empire comes in. What is the matter with Indian magnesite? If it be replied that Indian magnesite should continue to be used chiefly as a source of caustic magnesia for which in normal times there is a strong demand, the same is true of Grecian; and as I have already suggested, perhaps the iron and steel trade should look to the spathic types for its source of magnesite. From this point of view the Canadian (Quebec) deposits obviously merit attention. Have our manufacturers given this spathic magnesite of Quebec a fair trial? Canada is now shipping sinter which is claimed to have given every satisfaction to the Candian and United States steel companies, and one wonders whether, after all, in a spathic magnesite of the Canadian type, the objection to the lime is not mere prejudice. At any rate it might be advisable, from the Empire-independence point of view, to encourage a

fuller investigation and development of the deposits in Quebec and other parts of the Empire.

The questions raised by Mr. Donald as to the nature of the silicates formed in siliceous magnesite bricks, and the apportionment of impurities to secure the best results, are rather beyond the scope of my paper. I don't know what evidence he has for inferring that talc and chlorite are constituents of Grecian raw magnesite. As regards the rich assortment of silicates Mr. Donald takes into consideration in connection with the manufacture of magnesite bricks, one wonders whether their presence, in such considerable amounts as he implies, is at all good for the health of the bricks. I have not had the opportunity of making a thorough study of the microscopy of magnesia bricks. Such few observations as I have made, however, have given me the impression that magnesia bricks of good quality have a very monotonous texture, such as one would expect in material consisting essentially of crystalline magnesia. My impression is that the better their quality the less they offer in the way of interesting variety when sections of them are examined under the microscope. Hence I should regard with suspicion a magnesia brick the microsections of which exhibited such a veritable museum of silicates as is contemplated by Mr. Donald in connection with magnesia bricks.

For this reason I have much sympathy with the desire of both Mr. Donald and Mr. Mason to be supplied with a better quality of raw magnesite, though perhaps the importation of standardized sinter of good quality would meet the case better still. The magnesite producers in Greece no doubt look favourably enough on the export of magnesite containing plenty of serpentine. The exportation of high-grade sinter would be a more severe test.

With reference to the duration of Greek supplies, Mr. Donald says that the Grecian reserves have been greatly underestimated by the authority to whom I refer; but I think his remarks on the matter would be more impressive if they were backed by some particulars as to the situation and extent of the other deposits in Greece to which he refers.

I hope that Mr. Donald's optimism is well-grounded, and that when normal conditions return, British manufacturers will be able, from Grecian magnesite, to produce sinter and bricks which, for all-round economy and for ordinary furnace requirements, will be able to compete with the Austrian products.

Professor Fearnsides places on record the interesting fact that the texture of Austrian sinter becomes modified when the material is heated rapidly to a temperature of 1,500° C. and

is maintained for some time at that temperature. It seems scarcely permissible, however, to infer from this that the temperature of 1,500° C. was not attained in the sintering process. It would perhaps be more correct to infer that a material such as sintered magnesia, which is unstable in texture at a given high temperature on a first heating, is not necessarily stable in texture when cooled and afterwards heated again to that temperature.

Mr. Moore's very useful remark on the changes frequently observed when pottery bodies are re-fired, supports this inference rather than the one drawn by Professor Fearnsides.

Mr. Cosmo Johns' experience with bricks made from Styrian as compared with those made from Grecian magnesite appears to be in agreement with that of most others. It should be remembered, however, that Styrian sinter and bricks have been made for use at moderate rather than at unusually high temperatures, and it is as such a moderate basic refractory that Austrian sinter has had such great success, since it is adapted for ordinary requirements and has therefore met a large demand. A change of the ordinary requirements of metallurgy in the direction of higher-temperature processes would presumably tend to discourage the use of breunnerite as compared with purer magnesite; but as Mr. Johns points out, it is the magnesia and not the impurity that is refractory towards higher temperatures. Hence, so far as high-temperature refractoriness is concerned, I willingly share his doubts as to the desirability of adding impurities to dead-burnt pure magnesia, in order to degrade it to the composition of Austrian sinter.

Dr. Scott thinks that my sub-division of the magnesite-chalybite series tends to give the impression that the mixtures approximate to definite chemical compounds. I really hope this is not so, and I think that anyone who will note the contrast I have drawn between the definiteness of the chemical composition of dolomite, and the indefiniteness of the chemical composition of the intermediate members of the magnesite-chalybite series, will get the opposite impression, especially if he will compare the orthodox sub-division of the series with the one I have given. I might of course have gone into much fuller detail in dealing with this series, but a brief statement of the case seemed sufficient for the purpose of this paper.

Dr. Scott also thinks that magnesite as raw material should be considered from the petrological rather than from the mineralogical standpoint. Well, I think I have dealt with the subject pretty fully from the petrological point of view. I

have given strong prominence to the significance of dolomite as the important lime-bearing ingredient of spathic magnesites considered as rocks, and have shown that, contrary to Dr. Scott's assertion, dolomite is largely eliminated in the operation of dressing spathic magnesite and breunnerite.

I fear the suggestion that magnesites should be classed on the basis of the lime and iron contents of the rock is altogether unworkable.

As regards the effect of fusible silicates, I do not know of any satisfactory evidence that would lead one to regard them as desirable ingredients in refractory magnesia, except perhaps as a bond. So far as they are scattered sporadically through the mass, their presence seems obviously undesirable, and I am rather sceptical about their usefulness and significance as quickeners of the sintering process.

With further reference to the best way of dealing with magnesite as raw material, I think that one should look at the subject from all points of view, and not merely from the petrological, or mineralogical, or even both these standpoints. That is why I have cast the net wide in gathering information for this paper, which is on that account perhaps unduly long.

I am indebted to various firms and individuals for sending specimens, some of which were exhibited at the meeting. My thanks are due more especially on this account to the Director of the United States Geological Survey (Dr. Geo. Otis Smith), the Deputy Minister of Mines for Canada (Mr. R. G. McConnell), Mr. Wm. Donald of the Eglinton Silica Brick Co., Mr. J. D. Henderson of the Anglo-Greek Magnesite Co., Mr. T. W. Ward of the Fifield Magnesite Co., Messrs. Ridge-Beedle & Co., Messrs. Blackwell, Sons & Co., and the Magnesite Syndicate of India.

In conclusion, I wish to thank those who have taken part in the discussion for the added interest due to their comments, and The Ceramic Society generally for its appreciation of my paper.

VI.—Some Notes on Silica and other Refractory Bricks made from Non-plastic Materials.

By G. W. Mottram.

So much has been published during the last two or three years on silica and silica bricks that the ground has been pretty well covered, more especially on the scientific side at any rate, as regards the changes during burning, and also when in use in the furnace.

Burning might well be considered with advantage, particularly the debatable questions of "Up- *versus* down-draught," and why the Northerners use down-draught while the Southerners put their money on up-draught.

Then there is the duration of the burning of silica bricks, some burning 4 days, while others run to 10 days. One thing is certain, in these days of scarcity and high cost of fuel, the economical kiln is one of large capacity, running up to 100,000 bricks.

In dealing with materials where calcination is desirable, like magnesite and some silica rocks, this can be more effectively done, and at much less cost than in shaft or chamber kilns, by reducing the rock to a powder and passing it through a rotary kiln. A more uniform calcination is possible than is the case with large pieces, which are often seriously affected on the outer surfaces while the centre remains untouched. A saving in time, labour, cost and fuel, together with increased output, should bring the rotary furnace to the front. Whether the inversion of quartz can be wholly or partially effected by this method is a matter for investigation.

I propose introducing a new principle in the method of preparing the materials before moulding, which applies equally to silica, magnesite, chamotte, and all classes of refractory bricks made from non-plastic bases.

Some bricks are composed of a variety of materials, more or less loosely held together, a sort of conglomerate or pudding-stone formation, which is mechanically weak, and easily disintegrates on exposure to heat, draught, or atmospheric influences

Where more care is exercised in the manufacture the materials are given extra grinding, resulting in a less coarse mixture, with grains of a more uniform size.

Some makers go further with the grinding and consider that the limit of useful work has been reached when a fine sand size has been arrived at.

All these mixtures are more or less weak when made into bricks, due to the presence of voids. In fact, when the fractured face of a brick is examined with a lens, it usually presents the appearance of a quarry with a number of large caves.

The ideal brick to be aimed at—if the expression may be used—should be more of the nature of an alloy of the various ingredients, combining all the good qualities, and mechanically a much stronger article than is usually produced.

The practice of the Portland cement makers in grinding to 200-mesh, and even finer, can be followed by the brickmaker (for a proportion of his material) with great advantage to the strength of the resulting product.

In the early days of the cement industry the fineness of grinding was not considered as important an item as it is to-day. Crushing strengths of 200 to 300 lbs. per square inch were all that could be expected, whereas to-day 750 to 800 lbs. are quite a common occurrence with the best makes.

In important work, such as ferro-concrete, note the care with which the broken aggregate is graded, how the voids are filled with sand, and the smaller remaining voids with cement, until they will take no more.

Brickmakers should remember that this cement contains fine particles, less than 200-mesh, and is often used to the extent of 35 per cent. of the finished product.

In carrying out a series of experiments in 1916, with a view to production of bricks from calcined fireclay, I came to the conclusion that, in the ordinary methods of grinding refractory materials, whether by the wet process, using a solid bottom pan, or the dry perforated pan or ball mill, there was a marked shortage of the very fine material—sometimes described as impalpable—which is necessary to fill in the voids between the sand-size particles.

For instance, in grinding Sheffield ganister in a ball mill with 12-mesh screen, 25 per cent. passed 16-mesh and was retained on 20-mesh, 32 per cent. passed 20-mesh and was retained on 40-mesh, while only 16 per cent. passed 120-mesh.

To get the best result it is desirable to have such a gradation of sizes of grains, say from 200-mesh, or even finer, to the comparatively large particles about $\frac{1}{4}$ in. diameter (often

used in silica bricks), so as to produce a homogeneous whole.

Taking the firebrick industry as a whole it may safely be assumed that the average percentage of calcined fireclay, or grog, used in this country is in the neighbourhood of 15 per cent.

Using an average fireclay, with 50 per cent. calcined fireclay, prepared in the usual way by grinding together in a solid bottom pan, or with a perforated pan and mixer, it will be found rather difficult to get a sufficiently plastic mixture for moulding purposes. Even when the calcined clay is ground to 30-mesh, and the raw clay added as a fine slip, a mixture of 70 per cent. grog feels like sand when the moisture is reduced to 10 or 15 per cent.

Satisfactory results were obtained with 90 per cent. grog and 10 per cent. fireclay, when the raw clay was ground to a fine slip, with two or three times its weight of grog, and the resulting mixture afterwards mixed with the remainder of the ground grog. Bricks made on this principle, from calcined Stourbridge fireclay, showed no contraction after repeated burning, and after a week's exposure in the port of an open-hearth steel furnace came out with the edges quite sharp, as may be seen from the sample exhibited.

This method is specially applicable to the grinding and preparation of material for silica bricks. By grinding 15 to 30 per cent. of the material with lime, clay, or other binder to a fine slip, and then adding this mixture to the remainder of the graded silica material, there is not only the necessary fine material assured to fill in the voids, and act almost as a cementing medium, but *the binder is brought into intimate contact with every particle of the silica.*

With two such dissimilar materials as silica and lime—one very hard, and the other in a soft plastic state and only to the extent of 1 to 3 per cent.—it is not possible to get a regular and uniform mixture with a breaker, and 15 to 20 minutes grinding in a solid bottom pan.

Le Chatelier has been working on similar lines as regards the introduction of very fine grinding in the preparation of the mixture for silica bricks, and an article appeared in an English journal in April this year giving the results of tests of bricks made by a similar process in a French works.

1. With ALL FINE material the crushing strength reached 4,540 lbs. per square inch.
2. With "coarse" grains passing 100-mesh, and retained on 120-mesh, 993 lbs. per square inch.
3. With FINE + graded grains up to $\frac{1}{3}$ in. the average was 3,095 lbs. per square inch.

All these bricks were burned at 1,300° C.

The durability of bricks made on this system—in the same works—from similar material, and used under similar conditions, was some 200 to 300 per cent. in excess of bricks made with the usual method of grinding, and up to the time of publication they were "still going strong."

When ALL FINE grinding is used the permanent expansion can be eliminated, but in the preferred graded mixture amounted to 1·6 per cent.

With less voids there is an increase in the apparent density, which should result in increased conductivity.

I believe by this method of preparation many silica rocks, hitherto considered useless for bricks, will be utilised with satisfactory results.

DISCUSSION.

Mr. H. M. RIDGE:—I would like to ask the writer of the paper how he dealt with the raw materials. I understand that he has mixed one part of raw clay with two to three parts of grog, and then afterwards added a further amount of grog to make up the mixture. What was the time allowed between the two operations and how long did the whole take?

The reason for the question is that in some cases the use of the maximum amount of grog is desirable, but I have experienced difficulty in obtaining highly plastic refractory clay which would take as much grog as some of the raw clay I formerly obtained from the Continent without increasing the porosity of the finished article. If anything can be done by way of manipulation to permit of using a larger proportion of grog, this would be of the utmost importance.

Mr. T. ARTHUR ACTON:—This paper contains an ample field for discussion on many points, and seems somewhat at variance with the main principles we have hitherto regarded as essential in the manufacture of silica bricks. I do not quite agree that the writer's description of the structure of a good silica brick being likened to a "quarry" is particularly happy. However well the raw material may be graded and subsequently burnt, under magnification, the brick will show a certain proportion of interstitial spaces distributed throughout the glassy matrix of the brick, and these spaces are probably within certain limits rather advantageous than otherwise, as allowing for the further expansion of unconverted or partially converted quartz in the further heating of the brick during use; but this suggestion is at present only theoretical and put forward with diffidence. I quite agree with Mr. Mottram that the addition

of a higher percentage of very fine ground silica will probably be an advantage; but if I have understood M. le Chatelier's experiments and views correctly it is not because the fine silica flour is useful to fill up the voids or "quarries," as seems to be suggested by the writer of this paper, but that the fine particles of silica flour being evenly distributed through the raw material of the brick are more rapidly converted than the coarser material, and thus form a skeleton network or web which holds up the remainder of the material during the firing and conversion. The conditions of change during the firing of a brick are difficult to visualise and experiment on; the drawing of bricks at various stages of the firing and making sections is not satisfactory owing to cooling conditions being too rapid.

I think further experiments will prove that a higher proportion than is generally usual, say up to 15 per cent., of very fine ground silica will improve the quality of the brick, but the cost of grinding would be much increased.

Mr. P. N. F. SHEPPARD:—The sting of the paper appears to me to be in the tail. The last paragraph says:—"I believe by this method of preparation many silica rocks, hitherto considered useless for bricks, will be utilised with satisfactory results." This is a most unkind remark which has hit the Sheffield makers hard. I do not know if Mr. Mottram speaks as a scientist or a maker, but no doubt our Sheffield friends will now be able to use what we consider unsatisfactory material.

Mr. G. W. MOTTRAM:—In reply to H. M. Ridge: This question refers to the fireclay refractories. The mixing and grinding of the clay with two or three times its weight of grog to a very fine state is one operation, and the subsequent mixing with the further amount of grog, to make up the desired proportions, follows as soon as the requisite degree of fineness has been reached. Up to 95 per cent. of grog can be used, and the degree of porosity depends on the fineness and treatment of the mixture.

With regard to Mr. Sheppard's remarks, Sheffield ganister is admitted to be second to none for the manufacture of silica bricks, but their durability and strength could be considerably increased by the adoption of this system. Other silica rocks occur in the Sheffield district, which could be used for high grade silica bricks—by suitable treatment—at much less cost for the raw material.

In reply to general observations: Judging from references to problematical drawbacks which silica bricks, made on this

principle, might possess when in use, it would be inferred that *all* fine grinding was suggested. This is not the case. A graded mixture, containing large particles, as used in the ordinary method of making, gives the best results.

Reference has been made to a works practising fine grinding, but the fact that this was for enamelled bricks, and not for the refractory side of the business, was overlooked.

Mr. Acton's statement that "It looks like a quarry with a lot of caves," was made by a silica brick manufacturer on looking at a fracture of one of his bricks with my lens. This very apt description can be easily confirmed by examining any average silica brick in which coarse particles are used.

The part played by the very fine material in the making of any kind of refractory brick is to produce a stronger article, and the filling of the voids is incidental. In silica bricks this fine material is more rapidly converted than the larger particles, and this is one of the advantages claimed over the ordinary method of making.

Fifteen per cent. of the very fine is a decided advance on the present practice, but 25 per cent, and sometimes more, is preferable.

The extra cost of grinding—with a properly arranged plant—is not a serious matter, as is evident by the price at which Portland cement (180 to 200 mesh) can be sold in normal times. The entire costs at some cement works, including raw materials, two grindings and burning, only run from 12/- to 14/- per ton.

The fine grinding, in the case of bricks, only applies to a proportion of the finished article, and not to the whole product as is the case with cement.

VII.—Apparatus for the Charging and Drawing of Potters' Ovens.

By M. P. Ferneyhough.

In the summer of 1916 Dr. Mellor was good enough to suggest that I should give a paper on my apparatus. Two members made similar proposals, but I thought that it would be preferable to progress with the more important experimental work before taking up your time.

The request having been renewed, I may perhaps be permitted to explain the proposition, although we shall have to wait until the engineers have themselves tested it practically before the machine is put on the market.

Accordingly I shall have to speak with some reserve, and to describe the method in which the machine is designed to work, rather than what it has done. I may say, however, that all the vital experiments have proved successful and the design is satisfactory.

At the outset, I may state that my remarks are based on the peace time or normal working of a factory.

Pottery ovens have to be set in and drawn on specified days of the week to ensure the regular working of the whole concern. The charging or stacking of the saggars in the ovens, and the subsequent removal or drawing from the ovens, are long and laborious processes. Although machinery has been introduced into many branches of the industry, these very important operations are still done by manual labour.

This invention (Patent No. 13,387/1915) is an attempt to reduce the heavy work, and to make this branch more congenial to the workmen and more profitable to the employer. I have recently been told by a manufacturer that he has long been of the opinion that the time has arrived when men ought not to be required to undertake this wearisome occupation.

The apparatus is intended to be used in four processes, viz. :—

Placing biscuit ovens.
Drawing biscuit ovens.
Placing glost ovens.
Drawing glost ovens.

By virtue of its construction, the apparatus will facilitate repairs to the oven, necessary after drawing or before placing.

No alterations to the oven are necessary. A man can get in and out of the oven when the apparatus is in position.

The apparatus falls essentially into the following parts:— A gantry or hoist, detachable transport arms or stages, and the outer standards.

Saggars which are conveyed on trucks can be run to the oven mouth, raised by the lift and transported to the desired place in the oven. In like manner trucks convey loaded saggars when fired, across the arms, when they are lowered and run into the saggar-house.

The hoist, which is built up of steel bars, of angle and other sections, is telescopic and adapted to be brought into a small compass. The sides are detachable. This will permit the hoist to be readily brought within the oven, or withdrawn as the case may be. This point is very important, because the apparatus must be capable of being used from the beginning of the operations, and be of service to the end if the maximum results are to be obtained.

The transport arms or stages are telescopic, as shown by the plan. There will be occasions when a short arm only will be required, *e.g.*, at the commencement of the drawing, and at the conclusion of the placing. As the top saggars are removed it will be necessary for the man to work towards the rear of the oven, in which case the arm can be lengthened, so as to save time and labour.

The outer standards can be used either extended or when closed. For the drawing of the oven their use is optional. It will be found that they will not be required except perhaps at the end, but during the placing operations it will be necessary to bring them into service extended to their full length all the time.

Saggars may be emptied at the oven mouth, if desired, but a quicker method is to run them out into a place where several women can remove the ware, and the saggars themselves pass on to the saggar-house. In order to facilitate this, saggars can be conveyed on miniature trucks, and in connection with the apparatus a line of tramway is proposed. This will establish a communication between the oven mouth and the saggar-house, biscuit or glost warehouse. The rails will be very light and the tramway portable. It will be laid on trestles about two feet high, and can be taken up and connected to another oven with very little trouble. The gauge will be narrow, so that the line can pass through doorways, and, if necessary, in and out of workshops, and of course the line can be curved. There is no reason why the line should not be taken straight through a workshop if desired.

It will thus be seen that trucks can pass from various parts of the factory to any of the ovens, or from the ovens to many parts of the factory. This will save a great deal of carrying. The line may be inclined slightly, in cases where that course is not detrimental to the contents of the saggar. Thus the benefits of gravitation are secured. Another point is, that the line will be a double one, but instead of the two tracks being side by side as in railway practice, one line will be fixed over the other. This permits the tramway to pass through doorways, as previously described, and the low trestles will be just high enough to enable the line to be used as a bench.

To return to the apparatus itself, it is in practice proposed to use it first for drawing the oven. When this operation is complete the apparatus is, without alteration, in immediate position for placing.

Drawing Ovens.

For the purpose of drawing the oven the forebung is taken out in the ordinary way. This is necessary, for the simple reason that two objects of the same size cannot occupy the same space at the same time. The hoist is then introduced in its collapsible form, placed just inside the doorway, and immediately extended, when it will assume the shape of Fig. 1. By means of tie rods the hoist is secured to the wall, and the tramway is connected up. Drawing may now commence.

The apparatus having been fixed in position, two men ascend the hoist, and stand in a convenient position near the top. The cage which contains an empty truck is wound up, and the men, having removed a saggar from the bung, place it upon the truck. The weight of the saggar and its contents will cause the cage to descend, and when it reaches the bottom of the lift the truck is immediately discharged, and runs by gravitation to the saggar-house, or to the appointed place for emptying, conveying, of course, the goods.

While that cage has been descending, the other one by virtue of the mechanism employed has been ascending, also carrying a truck. This gives the workman, who is on that side of the oven, an opportunity of disposing of a saggar from another bung. He places the saggar on the truck and the cage descends, the first cage going up again. Thus they continue, each in turn lifting the saggars on to the cages instead of handing them down to men beneath, who pass them to others still below. Drawing proceeds by the removal of saggars on each side equally.

This goes on until a number of saggars have been withdrawn. It will be seen that in a very short time the men will

get out of convenient reach of the lift. To avoid walking over the saggars, or even undue reaching, the transport arms are introduced, being, of course, in their folded or collapsed state because, as yet, there is not much room in the oven. One end is simply ledged on the hoist, the other rests on the saggars, and drawing continues.

The cage is raised, carrying an empty truck which is on the lower deck. The truck does not stop on the cage when the top of the lift is reached, or the workman would not derive any advantage. By means of a spring pushing device the truck is automatically transferred to the arm, travelling, of course, on the lower member, which coincides with the lower deck of the cage. I am of opinion that it may be found convenient to send up another empty truck so as to have one in reserve. This travels also on the lower arm, which is reserved for empty trucks, the upper arm being for loaded trucks. There is, therefore, at this stage, two empties on the arm.

One empty truck is transferred to the upper member of the arm for loading—preferably by a boy—a saggar is put on, pushed towards the cage, which receives it on the upper deck. Simultaneously a further empty is discharged from the lower deck as before described. The cage, full truck and all, instantly descend to the base where the truck runs off, and another empty is placed on to be used in due course.

During the few moments this cage is at the base the other cage is at the top, discharging its empty to the transport arm, and receiving a loaded truck, the weight of which causes the cage to descend while the first cage goes up once more. So the process is repeated over and over again.

In quite a short time it is considered possible to remove an appreciable number of saggars, all of which will be removed from the top in much the same way as at present. The arm is lengthened as occasion requires, and will stretch to the rear of the oven. Thus the trucks can travel from the back of the oven to the lift, are lowered, and pass on for emptying without intermediate handling.

The boys in attendance at each arm will be fully occupied in transferring trucks from the lower member to the upper one, and in giving these trucks a gentle push as the workmen put the saggars on. These operations are the work of a few moments only. Consequently there is a continuous stream of trucks running on to the cages alternately from two different parts of the oven. The lift is in constant motion lowering saggars, and all the time it is supplying empties at exactly the same speed as loaded trucks are received. Therefore there is no waiting for empties.

If we transfer our view to the oven mouth, we shall see a loaded truck discharged and an empty put on. The cage ascends, and in a moment the other cage appears with its load, and so the stream of trucks travel to be emptied, and the quicker the emptying is done the quicker the oven is drawn.

Individual articles of pottery are not heavy, so that the saggars can be emptied by women. Where it is possible for two women to stand on opposite sides of the "tramway bench" they can empty a saggar very quickly, and if several be so employed the drawing is greatly facilitated. The time of the whole team is reduced, and consequently the expense of the drawing of the oven. If the oven is "out" sooner, it is available for use sooner, and if the oven is used a greater number of times during the year there is a corresponding increase in production.

A manufacturer who can arrange for the saggars to be emptied in or near a glost warehouse will avoid a great amount of carrying. Attention to these small details means eliminating waste labour which, of course, saves expense. In some cases ovens pass through the building, and the warehouses are on the first floor, but that is not an obstacle. The saggars can be delivered straight to the warehouse through an upper clamin. By reason of a circuit that will be established, the empty saggars may be discharged in the saggar-house in the ordinary way.

In some large factories the biscuit warehouse is situated an appreciable distance from some of the ovens. The trucks will, by gravitation, carry the saggars for the purpose of emptying, and much heavy labour will be abolished. Different conditions obtain in different factories, but the proposals outlined can be adapted with advantage to all.

A great deal of loss is caused by the present method of handing down saggars. It is a common practice for saggars to be tilted when handed by the man at the top to the man below, and he again tilts the saggar when passing it on. One article of ware falls against another, damaging both, hence a certain amount of seconds and lump. It will be observed that the transport arms remain horizontal throughout, and if they slope it will only be in consequence of deliberate neglect on the part of the workman. This arrangement is designed specially, so that every saggar will remain horizontal from the time it is deposited on the truck until it reaches its destination.

When the "top" of the oven is drawn, the transport arms are lowered so that the middle can be dealt with, and later one arm is lowered to the base of the lift, and trucks run straight in and out. In all cases the arms may be moved laterally when required.

As soon as the drawing is finished, the oven may be swept out as usual, and it will be found that the apparatus will not be in the way. The outer standard, Fig. 2 (*e*), having been fitted while this is going on, iron boxes may be filled with roll bits and shraff, placed on a truck, conveyed out of the oven and delivered where required.

Repairs to the Oven.

Repairs are frequently found necessary to the interior of the oven, after drawing, and before placing. There is no need whatever to remove the apparatus. On the other hand it may be found of great service. When the repairs are required at the base, the arm can be fixed at a convenient angle, and fire-clay, bricks and other materials delivered on a truck to the point where the bricklayer is working. If repairs are needed to the side of the oven, then the transport arm is raised to the height required by the bricklayer, and the materials will be ready to hand.

Charging the Oven.

The actual filling or placing of the ware can be done by women placers, when the saggars are on the trucks, ready to be gently moved to the oven mouth. The moving of the glost saggars when full is a very delicate operation, and is one of the greatest difficulties which has to be contended with.

The charging or stacking of the oven will proceed in much the same order as at present. Two workmen who have had experience as placers will be required within the oven, preferably on opposite sides thereof, so as to have the advantage of each transport arm. They will commence with the outer ring, being served or supplied with saggars on the transport arm, each man building up bungs at the same time, and proceeding until the bungs become so high so as to be out of convenient reach. Having deposited as many as possible at the base the transport arm is altered to the intermediate position. The placer then ascends the hoist and takes up a position upon a platform adjacent to one of the arms or stages to which the saggars are raised, and continues the outer ring. Having completed the intermediate position the arm or stage is wound up higher in order that the bung may be stacked up to the top.

Where possible, I am of opinion that it will be an advantage to place as many bungs as possible simultaneously. In this way it will be found that a very large number of saggars can be stacked without moving the arms.

For the purpose of charging an oven the apparatus is worked in the reverse way to the method adopted for drawing.

At the oven mouth the trucks are put on the upper deck of the cage, not on the lower deck, and they are automatically delivered from the hoist at the intermediate, or upper stages, travelling always on the upper arm. This arrangement has been specially designed so that the operative within the oven can see inside the saggar before he touches it. In this manner the placing of the oven proceeds and the transport arms are moved from stage to stage. They are shortened as the bungs fill up the centre, being finally lifted off and removed when the doorway is approached. Eventually the outer guides of the hoist are taken down, the hoist telescoped, and withdrawn. The few saggars constituting the forebung are stacked up and the doorway is sealed for firing.

From the foregoing it will be observed that most of the heavy work in connection with the oven operations is abolished.

General.

Although the apparatus is collapsible and telescopic the telescopic parts are not in constant motion all the time. First the lift is introduced and erected. Then the telescopic arms are used, just in the condition in which they are brought into the oven. As the drawing proceeds the arms are extended, and when space permits they are extended further, and can also be moved about laterally. When the top of the oven is drawn the arms are lowered, and the lifting mechanism so adjusted, that the cages and arms can serve the middle portion of the oven. Lastly, one of the arms is lowered to the base, and as the saggars in consequence of their removal cease to support the outer extensions, the standards are brought into play. The oven being empty, the floor is swept, and repairs done without removing the apparatus, which is in immediate position for placing. The transport arms are moved laterally so as to be near the outer ring of the oven, and, as the bungs rise, the arms are raised vertically first to the intermediate and then to the upper position. When the outer ring is complete the arms can be pulled over for placing the inner rings. Gradually the space between the oven gets filled up, and the arms are shortened by telescoping, the winch arrangement permitting this to be done very quickly. The standards and arms were eventually withdrawn, and lastly the hoist itself.

Thus the apparatus commences "small" as it were, when there is very little room, branches out as occasion requires and remains so extended until the utmost advantage is derived from that position. Lastly it closes up, and is removed when

the oven is filled up. In other words, the apparatus accommodates itself, all the time, to the prevailing conditions within the oven, whatever the conditions may be.

Two capable placers are necessary with the assistance of boys, and also the oddmen for stacking saggars in the saggar house. The saggars can be filled and emptied by women, except perhaps heavy flat. In factories where the ovens are small I am of the opinion that the apparatus can be worked with what I have called a "half team," that is to say, one man and a boy in the oven, drawing or stacking, and the other hands reduced accordingly. It would be desirable for the team to be in the charge of a head placer who should understand the apparatus. In any event it is expected that the cost of the oven operations will be reduced and the work done more quickly. I am hoping that in consequence each oven can be used a greater number of times per annum.

A manufacturer, having ovens of different sizes, will not be under any disadvantage in that respect. The contingency has been provided for. It is possible for one lift to be made to serve any oven, and the arms and outer standards adjust themselves.

A question may arise, "If women operatives are to be employed, what is to become of the men thus thrown out?" My answer is this: "Machinery frequently has the effect of displacing labour, and as a rule, cruel though it may seem, it is not the business of the inventor to concern himself about the men who are thrown out of employment." I am, however, in this very happy position. If the apparatus will work in the way that it is intended (and, after careful enquiry, I have reason to believe that it will), the number of ovens per annum from each factory will be greater. Other things being equal, the production of each factory will therefore be greater and more men will be required to make the additional ware, and see it through its various processes. I shall, therefore, propose to manufacturers that they utilise the services of these men in other departments.

I trust the time is not far distant when the machine will not only justify the designer's intentions, but prove to be an appliance that, in the opinion of a firm of manufacturers "promises to be of valuable service to the district."

DISCUSSION.

Mr. T. A. SIMPSON:—I have much pleasure in moving a vote of thanks to Mr. Ferneyhough for his interesting paper. If the apparatus should prove to be of practical use, then the

inventor may be sure that not only will manufacturers welcome the idea, but he will have earned the gratitude of the ovenmen in easing their laborious task. There is one point that does not seem to have been explained, viz: How is it proposed to deal with the saggars from the bottom up to the height of 6½ feet or so of the stand? Perhaps Mr. Ferneyhough will deal with this point in his reply.

Mr. HERFORD HOPE seconded the motion.

Mr. JONES:—How long would it take to empty a 20 feet biscuit oven with the use of this apparatus?

Mr. FERNEYHOUGH:—So far the apparatus has only been tested experimentally, and I am unable to state a definite time for drawing a 20 feet biscuit oven, but a very considerable saving in time is hoped for. I think the time taken will only be half of what it is at present, if not less.

As regards the point mentioned by Mr. Simpson, the placer would simply lift the saggar off the truck and place it on the bung in question. The placer is served with saggars already filled. In this case the arm would be in the lowermost position, only 3 or 4 feet above the oven floor.

Mr. A. LEESE:—The plan looks admirable on paper, but may not answer so well in practice. The apparatus seems very flimsy, and liable to get out of order. Time would be wasted in adjusting it to different heights, and in the top or bottom cage waiting for the other. Another disadvantage would be caused by the vibration, which would be the greater the flimsier the apparatus. Coming from the top of the oven downward is the great drawback, where a lot of time is lost when the saggars have to rest at the top and bottom angle of the apparatus. If the door opening of the oven could be extended upwards it would be possible to have an inclined plane, adjustable to different heights, down to the saggar-house or warehouse, to work in the form of an endless band with carriers pitched horizontal carrying the saggars to and from the oven.

Mr. FERNEYHOUGH:—The points mentioned by Mr. Leese have already had careful consideration. Well engineered, on modern structural lines the difficulties mentioned should not arise, as they have been provided for. The arms are designed to permit of rapid adjustments, and the cages will be made to work at speed. The model is quite rigid.

Mr. W. E. GOODWIN:—Has the lecturer a model of this apparatus, with which he could give a demonstration at some future meeting?

Mr. FERNEYHOUGH:—Models of the apparatus are in existence, including one on the full scale, and these have been very successful. It is hoped that before long the apparatus may be seen in operaton.

Mr. G. REYNOLDS:—We had an electric ladder made a few years ago at Gustafsberg, Sweden. It was found that it got very much in the way, though it worked well enough in itself. We found the trouble arose when the drawing was taking place more than when placing. The 18's and 20's dish saggar were too large to get past the structure which we considered an obstruction.

Mr. J. WILLIAMSON:—As I am not a potter I cannot criticise from that standpoint, but having had experience of the mechanical handling of materials I can congratulate the author on his attempt to deal with a most difficult problem. If I might offer him a suggestion it seemed to me that instead of placing his apparatus at the side of the kiln (seeing that his arrangement was telescoped), a better plan would be in a round oven to leave out the centre bung, and drop his apparatus through the centre and have four or more swinging derricks arranged so as to be capable of being worked at different levels and at any radius. Of course where an oven had a chimney in the centre this arrangement would not apply.

Judging from appearances the apparatus would be expensive and might cost £200 or more, and it is a question whether the cost of the apparatus, together with the cost of upkeep, would not be too great to be compensated by the advantage gained by its adoption. The mechanism seems very delicate and would require a certain amount of engineering skill to fix it up in position and maintain same in proper working order; but the men who usually carry out the work connected with ovens have not as a rule any engineering knowledge, therefore the machine should be as rigid and as simple as possible in its construction.

Again, round intermittent ovens are losing favour in many quarters, and the modern tendency is towards the substitution of tunnel ovens of the continuous type where all placing and drawing operations are done on the ground floor.

However, great credit was due to the author for the way in which he had tackled an extremely difficult problem, and I can appreciate the great amount of labour and thought which had been bestowed on this apparatus.

Mr. FERNEYHOUGH:—The apparatus is fixed just inside the doorway of the oven, so as to utilise the space at once

when the forebung is removed. It is intended to be set up in about ten minutes. The estimate of cost given is excessive. Though I am not in a position to name a price, I am hoping that by adapting standard sizes and shapes in steel or iron we may be able to put the apparatus on the market at a reasonable figure.

Round ovens are likely to remain in many works at any rate, because sufficient space is not available for tunnel ovens.

Mr. W. W. LINDLEY:—We had a man in the oven who received the saggars from twelve men placers and placed them on the bungs, he easily kept the men going and had time to spare. Two men could therefore easily keep fifteen to twenty placers going, moreover, the head placer could supervise the saggars as to being well filled, etc.

Mr. FERNEYHOUGH:—I said two men and two boys would be needed to work with the apparatus. We think of reducing expense by having boys instead of men. Probably a little experience will enable us to deal with the matter in a satisfactory manner. I am very pleased this point has been raised, it is a very important one.

Mr. J. JOHNSON:—In an apparatus of this nature, a frequent cause of trouble is the jamming of cages. This is not a mere supposition, but has been actually experienced. Difficulties of this kind will have to be faced.

Mr. FERNEYHOUGH:—I was not aware that anything of this kind had been attempted so far. It is hoped that the machine will work satisfactorily with a reasonable amount of care. An engineer should be able to make the cages so that they run smoothly.

VIII.—Study of Silica Products (Part II. Bricks, etc.)[1]

By Dr. A. Bigot.

(Translated by J. A. A.)

ONLY silica products used in the Martin or similar furnaces are to be considered. This manufacture is carried out with compact siliceous rocks, which I described in a previous paper. These rocks are suitably ground, and about 2 per cent. of slaked lime is then added, with sometimes a little clay or ground bauxite; the whole is worked up into a body, which can be moulded directly in metal moulds or by means of a machine-press which gives sharp angles; it is not necessary to employ a powerful pressure. The pieces are afterwards dried and then carried to as high a temperature as possible in the kiln. Silica products met with in commerce can be arranged in three categories, although this classification has nothing absolute: (1) Those which include large grains, (2) Those which include medium grains. (3) Those which include small grains. These grains of rock, large or small, are all surrounded by a fine mass, made by the mixture of finely ground lime and silica, forming a kind of cement adhering to the grains of rock.

The study of silica products includes three principal series: (1) Analytical studies. (2) Physical studies. (3) Micrographical studies.

Analytical Studies.—Analysis of silica products can be made by two processes: either by quantitative determination of each of its elements or by estimation in the state of sulphates of the elements other than silica. In this last process, which is rapid but imperfect, the lime, alumina, etc., are treated all together, without paying attention to their proportions; but it is indispensable to know the quantity of alumina contained in these products, for, if it is in excess, it brings about a lowering of the softening and fusion points.

Physical Studies.—Physical studies of silica products comprise observations on changes of volume, density, porosity, and mechanical resistance, under the influence of high temperatures. For this purpose tests are carried out: (*A*) On products

1 Part I.—Raw Materials—appeared in Trans. 17, 1918.

such as proceed from factories. (*B*) On the same products submitted to the temperature 1,710° for an hour or two, or to 1,650° for the time necessary for their complete expansion.

A. Tests on products made by the trade.

This first group of tests includes determination of density, porosity, and resistance to crushing at ordinary temperature.

Density.—Apparent density and absolute density are measured; the measure of this last provides a first indication of the thermal conditions in which the product was burned. The density of quartz is about 2·66; under the action of heat, when it attains its total increase in volume, the density is about 2·32. Quartzites present analogous results. The density of flint varies between 2·60 and 2·62; after burning at a high temperature this density is no more than 2·22. The small quantity of lime and of foreign matter which is found in silica products based on quartz or quartzite has but little influence on their absolute density; it is sufficient then to measure this absolute density in order to have an indication as to the burning of the products. If for example this absolute density is not less than 2·45—2·50, it is certain that the burning has neither been high enough nor long enough; if this density is below 2·40 and tends to approach 2·35, then the burning can be considered satisfactory. Silica products based on compact flint present smaller absolute density, which should approach 2·25 and tend towards 2·22.

Porosity.—Porosity is then determined by finding the weight of water which the very dry siliceous product absorbs after a 24 hours immersion in water. Porosity depends on several factors, and particularly on the nature of the rock, the size of the grains, the composition of the cement, etc. Certain bricks have a porosity of 8 per cent.; others have higher porosities, sometimes reaching 20 per cent. This porosity should decrease when the products are heated to 1,710°, if they are of good quality; too great a porosity facilitates absorption of slags in the Martin furnace and accelerates wear of the bricks.

Resistance to Crushing at Ordinary Temperature.—The resistance to crushing is very important. In the Martin furnaces, and especially in their arches, the part of the products which is in contact with the gases in combustion increase in volume, the arches swell, and pressures—often very high—result in different directions. Just at the periods of tapping or of changing the furnaces there are great variations of temperature, which bring about contractions or expansions. During these operations the bricks should resist changes of pressure without being crushed or cracked. The resistance to crushing at ordinary temperature is measured by the process adopted by

the Conservatoire National des Arts et Metiers, where half-bricks are operated on. This resistance depends on the quality of the grains of the rock, and the quality of the cement which surrounds them; it is greater when the porosity of the products is small. According to the physical properties of the products the resistance to crushing varies from 120 to 500 kilog. per sq. cm.

Tests after Heating at 1,710°.

It is preferable to proceed with these tests on whole bricks which have been heated to 1,710°. This operation is performed in a recuperating furnace, Bigot and Bodin's system, which will be described in a subsequent paper. After this burning, if the condition of the pieces permit, their expansion, density, porosity, and resistance to crushing when cold and at the temperature 1,500° are determined. When taken from the recuperating furnace, after heating to 1,710°, the pieces appear under two different aspects accordingly as they have clearly been softened and deformed, or have melted; in both cases they are of inferior quality, and are not suitable for use in the Martin furnaces. Where they have resisted without either melting or being deformed, three principal cases occur: (1) As the temperature is raised, the siliceous grains increase in volume and porosity; the cement which surrounds them is partially vitrified, contracts, and resists (without cracking) the expansion of the silica grains. Experience proves that the porosity of these products decreases in proportion as they are taken to higher temperatures, and that the best silica products present this peculiarity. (2) Porosity, on the contrary, has increased, and, when the products are carefully examined, on coming out of the furnace, they are found to be cracked; the grains of rock which they included have expanded too much and have broken the cement which enwrapped them. This case is frequent when the products are made with the grains too large, and which expand too much. These cracked products become friable, their resistance to crushing has decreased greatly, their porosity has increased, and they are easily attacked by the slags and dusts of furnaces. If the manufacturer wishes to make use of a rock whose increase of volume is considerable, he should grind it more finely and give up the employment of large grains in his products; the following demonstration illustrates this principle: In the case of Souvigny quartzite, which expands 10 per cent., and a quartzitic Armorican sandstone which expands 15 per cent., the volume of a cube of the first with side 10 becomes 1,331 at 1,710°, and a similar cube of the second becomes 1,520; the volume of the first has

increased 33·1 per cent., and that of the second 52 per cent. or more than half of the original volume. Then in order to realise a similar increase of volume with manufactured products by means of these two rocks it is necessary to employ the Armorican sandstone with finer grains than those of the Souvigny quartzite. (3) Porosity after heating to 1,710° has slightly increased, resistance to crushing at ordinary temperature has perceptibly decreased, and resistance to crushing at 1,500° has become zero.

Careful examination of these products furnishes proof that their grains of siliceous rock have become friable, the chief material employed being such as falls into powder at 1,710° as I described in the study of the rocks. The porosity of these grains has increased considerably; the cement which enwraps them has preserved its consistency and has not cracked; it is that which maintains in the product a certain resistance to crushing at ordinary temperature; but when a trial is made for resistance to crushing at 1,500° the cement softens, and, the grains no longer having any cohesion, the products are crushed under an insignificant pressure. The quality of these products is defective; it is like those which are made with a mixture of rocks of good quality and of rocks which have become exhausted at high temperature.

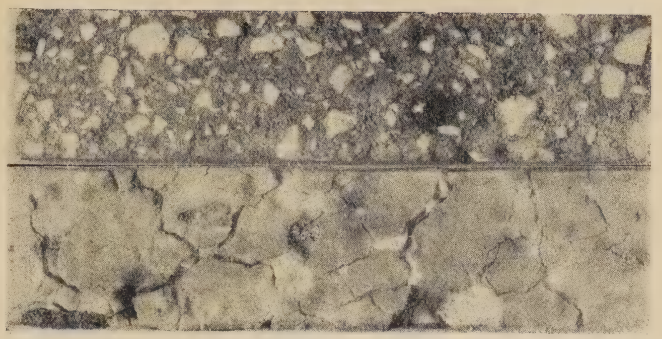
Fig. 1 represents the photograph of a cut piece of silica brick which, after burning at 1,710°, has fully expanded, and of which the mass has remained quite homogeneous; its porosity was 12 per cent. before firing, and it fell to 9·70 per cent. afterwards. Fig. 2 represents the photograph of a piece of brick with two large elements, which cracked very much at 1,710°; its porosity was 9 per cent. before the firing, and it increased to 15·60 per cent. afterwards.

The crushing tests at both ordinary and high temperatures were made at the Conservatoire National des Arts et Métiers, by Captain V. Bodin, Head of the Materials Section, who was acquainted with the idea of adapting a special contrivance to Frémont's machine for measuring crushing resistance at all temperatures up to 1,500° This new method has given very interesting unexpected results, and forms the object of a special description annexed to the present article. (See Appendix II).

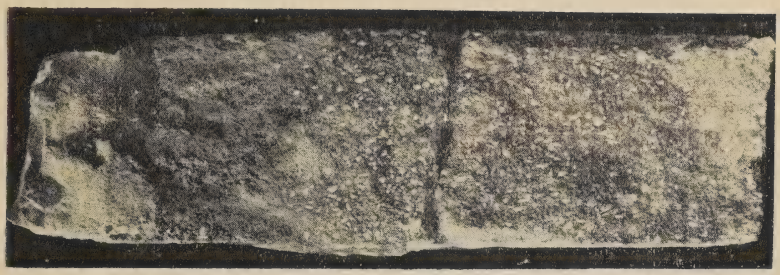
3. *Micrographic Studies.*—The study of silica products with the microscope permits the determination of the nature of the chief materials employed and their successive transformations; it is established that tridymite is formed rather rapidly in the presence of lime at high temperature; this formation is much slower in the parts of rock grains which are not in contact with the lime.

(1)

(2)

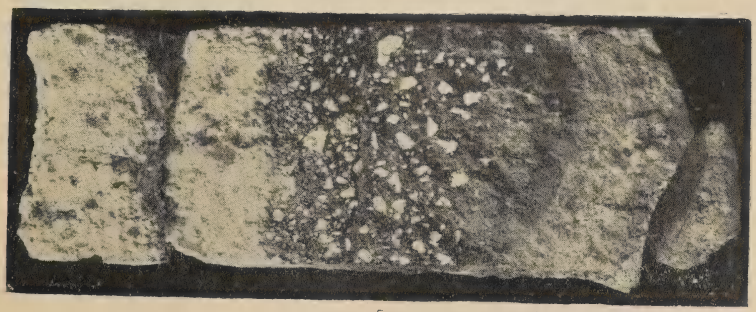


Figs. 1 and 2.



D E F

Fig. 3.



D E F

Fig. 4.

IV.—Manufacture of Silica Products.

It is rather difficult to state now precise rules on the subject of this manufacture, on account of the variety of the principal materials. From my numerous experiments and from various works hitherto published, the principal qualities of silica products can be put under four heads: (1) Refractoriness as high as possible and above 1,710°. (2) Increase of volume as small as possible. (3) Crushing resistance as high as possible when hot and at ordinary temperature. (4) Small porosity. I would wish still to draw attention to two particular points: the grinding of the rock and the burning of the products.

Grinding of the Rocks.

Hitherto manufacturers generally employ, for grinding, vertical mills of more or less heavy weight; the ground material is afterwards sifted in order to separate too large grains, which are brought back for grinding; the apparatus used in the sifting room allows no separation of very fine elements, fine, medium, and coarse. Vertical mills, in grinding the rocks, destroy a part of the angles; the ground material which goes from the apparatus never has a constant composition because it remains for a longer or shorter time in contact with the grinder, or because the pieces of rocks to be crushed offer very variable resistances to crushing. It is certain that manufacturers will be induced, sooner or later, to make use of processes analogous to those used in the abrasives industry; crushing of the rock, grinding in cylinders and sifting, which allows classification of the grains and separation of the fine dust, constituting the basis of the cement which serves as agglomerant. These processes give grains with sharp edges, indispensable for this manufacture; they allow exact determinations of the proportions of grains of different sizes separated by the sifting rooms to be made. Manufacturers will thus have the possibility of making products with angular grains, of constant composition as regards grain size, and including a known proportion of fine. To-day none of them attain all these conditions, which are indispensable in order to obtain a product of constant composition and quality.

Burning of the Products.

The burning of these products requires as high a temperature as possible; from observations which I made, 1,600° should be approached as near as possible. At this temperature a few hours' firing suffices in order to obtain a good result. At present most of the manufacturers make use of intermittent

kilns, which only permit temperatures above 1,400° to be obtained in the middle; it is necessary then to maintain the products at this temperature for long periods in order to obtain a transformation and a partial expansion of the silica with consequently a considerable expenditure of fuel and a much longer burning. In some of these kilns the setting in, the burning, the cooling, and the drawing from the kiln, require about three weeks.

As a result of repeated trials which I have made in my tunnel kiln between 1,500° and 1,550°, I have proved that the

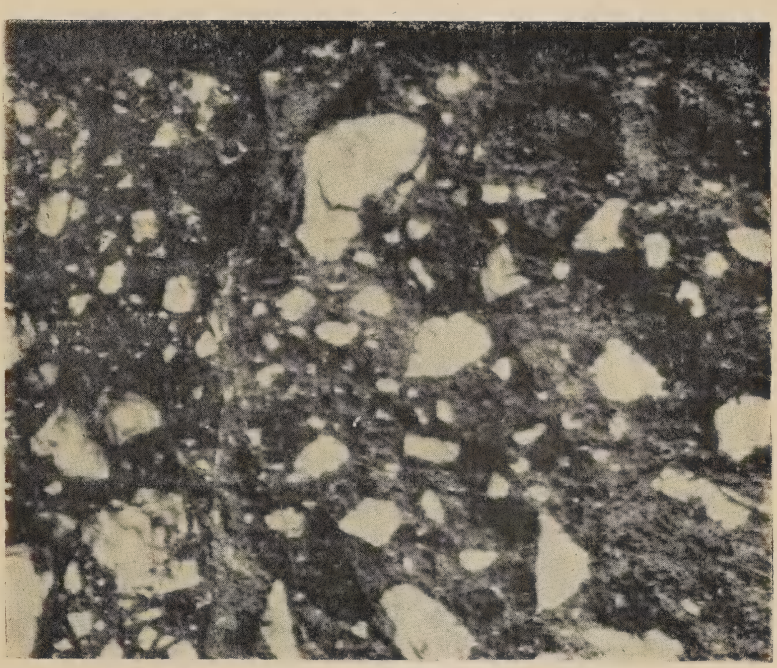


Fig. 5.

duration of a good burning, according to the tonnage to be produced per 24 hours, varies from 4 to 5 days from the moment the products enter into the tunnel until the moment they go out of it. This tunnel kiln expends scarcely a third of the fuel consumed by the burning of intermittent kilns. In another article on my kilns with high thermal efficiency I will describe laboratory kilns and industrial kilns which I erected, and which permitted me to undertake the study of refractory

products requiring a burning at high temperature and also the economic burning of these products.

Appendix I.

Studies of Silica Bricks which had been in the Martin furnaces.

It appeared to me interesting, in order to complete my study of silica products and their manufacture, to publish the results of experiments which I made with silica bricks which had been in the arches of the Martin furnaces. These results allow certain further researches to be considered in a new way. The bricks studied proceed from the arches of the Martin furnaces of Creusot, acid furnaces and basic furnaces.

Fig. 3 is the photograph, two-thirds of the natural size, of a silica brick which had been in the arch of an acid furnace; this brick, cut into the length, is rather fine-grained. Fig. 4 represents, in the same conditions, a brick of medium grain, proceeding from the arch of a basic furnace. Fig. 5 represents an enlargement of the preceding in the middle part; the grains are four times the natural size.

These two bricks show three very distinct zones, *D*, *E*, *F*, which are clearly visible, especially in Fig. 4. The upper zone *D* is constituted by the unattacked silica brick. The intermediate zone *E* is brown; it includes, disseminated in its mass, white silica grains, analogous to those of the part *D*, and of which the size decreases in proportion as the lower part *F* is approached. These white grains are attacked by degrees by the brown matter which surrounds them; this attack is produced at their external surfaces, but, if they are cracked, the brown material penetrates to the interior of the cracks and the attack becomes more rapid; this phenomenon is visible in a certain number of grains of the enlarged figure No. 5. The lower zone *F* is grey; it no longer contains white silica grains, visible to the naked eye. The lower surface of this grey part, in direct contact with the furnace atmosphere, is brilliant and covered with a kind of brown glaze; it is hollowed in time by partial fusions which were produced there by contact of the dust and slags of the furnace. The researches on these bricks comprised three series of studies: (1) Analytical studies. (2) Physical studies. (3) Micrographic studies.

1. *Analytical Studies.*—The brown part is three or four times more voluminous than the grey part; both have variable compositions according to the zones where the previous deductions are made for the analyses; the grey part, which is in contact with the furnace atmosphere, has not quite the same

composition as that which is in proximity to the brown part; even this last has compositions a little different according as it is more or less approached by the grey part or the unattacked part.

The nature of the metal, of the fluxes, of the fuel, of the silica bricks, etc., equally influences the composition of the grey parts and of the brown parts. Yet the bricks proceeding from basic or acid furnaces present the same peculiarities; their grey parts have analogous compositions and physical properties; it is the same with their brown parts and, until now, I have not been able to find in the grey or brown zones special characters which can be attributed to the action of acid or basic furnaces. As example I will quote the means of two series of analyses:

	Silica	Lime	Magnesia	Iron Oxide	Alumina	Manganese Oxide
Grey part ...	84·60	3·55	1·05	9·25	0·60	0·95
Brown part ...	78·45	4·95	1·15	13·10	1·20	1·15

The iron in the grey part is in the ferrous state, and is not attracted by the magnet. In the brown part it is partially in the ferric state; about half is attracted by the magnet. The grey part is in direct contact with the furnace gases, whilst the brown part is submitted to the action of the external air. The furnace gases reduce iron oxide in the grey material; it is not necessary, in order that this reducing action be exercised, that the general working condition of the furnace shall be reducing; it is known that in the combustion of the gas, even in general working oxidizing conditions, certain zones are reducing. Lighter than the oxidizing gases, the reducing gases traverse the porous body more rapidly, in consequence of the phenomenon of osmosis. In contact with these reducing gases the iron compounds pass into the ferrous state in the grey part; on the contrary, under the action of the external air, the iron passes into the ferric state in the brown part.

In proportion as the grey part is corroded gradually at its base by the materials which happen to be vitrified and melted there, its depth increases, the black part is approached by the furnace gases and the ferric oxide which it contains passes into the ferrous state about the base; a fresh quantity of brown part is formed at the expense of the unattacked portion, and so the total depth of the brick decreases progressively. This phenomenon of osmosis of gases is not peculiar to the Martin furnaces; I have many times observed and studied it in the manufacture of enamelled ceramic pieces burned towards 1,250°—1,300°. In the normal oxidizing working

conditions of the oven (or kiln), if enamelled pieces be burned, some in saggars, others in the naked fire, in the same part of the furnace, the enamels of the pieces placed in saggars present the characters of reduction, the others present the peculiarities of colours produced in oxidizing flame, for the reducing gases, traversing the saggar walls, introduce inside the saggars a reducing atmosphere.

There is occasion to remark that the proportion of iron and oxides other than silica is more abundant in the brown parts than in the grey parts, though these latter may have been brought nearer to the surface of the slag and metal in fusion; till now the exact explanation of this phenomenon has not been given.

2. *Physical Studies.*—Fusion points. I have determined in a fairly exact manner the fusion points of the materials *D*, *E*, *F*, compared with those of fusible decimal standards; for that purpose I ground very finely each of the three different materials, with which I made cones which served as fusion trials. (1) The cones made with grey material, brown material, and unattacked brick were first carried in the same time to the temperature at which the decimal standard 169 bends (1,690°); the three cones remained intact. (2) In another experiment at 1,710°, at the moment when the standard bends, the cone made with the brown material *E* melted completely, though the cones *D* and *F* only began to get rounded at the point. (3) In a third series of experiments I proved that cones *D* and *F* and the standard 173 were bent in the same manner, though cone *E*, formed of brown material, melted like glass and was completely absorbed by its refractory support. The brown material *E* did not pass through the pasty condition like the materials *D* and *F*, but melted and liquefied abruptly.

In the Martin furnaces deep hollowings of the arch have often been observed, proceeding from fusion of the silica bricks; this irregularity is, when bricks of good quality are employed, due to flashes which bring about fusion of the brown part of the bricks, and, in time, to a defective behaviour of the furnaces from the point of view of regulation of the temperature. In order that the grey zone of the brick can be formed, which is indispensable according to tests which will be described further on, it is necessary to properly regulate the average composition of the combustion gases, and a semi-oxidizing and semi-reducing working condition appears to be preferable.

The stability of the bricks and silica products depends not only on their manufacture, but it depends also on the behaviour of the furnaces in which they are used; this behaviour varies

according to the works and the persons who direct the manufacture, and until to-day manufacturers of silica products have remained in complete ignorance of the way in which their products are employed and behave in metallurgical furnaces. In order that the industry of silica products may progress rapidly, it is necessary that manufacturers and consumers should be heard one after another in order to solve all the difficulties which are met with in this industry.

Expansions.—The part *E* of unattacked brick, carried to 1,710°, presents an average linear expansion of 2·75 per cent. In the arch of the Martin furnace the grey parts have an average expansion of 2·50 per cent., and the brown parts an average expansion of 1·75 per cent. These figures are not absolute, but they make it evident that the arch bricks have already taken a partial increase of volume, in their parts in contact with or near the combustion gases. The foreign matters, proceeding from the slags or the dust of the furnace, simply choke up the pores in the expanded parts of the bricks where they penetrate by capillarity, forming the brown material. Chemical action of the foreign materials begins as soon as impregnation is established. Disaggregation of the silica product is continued more or less quickly according to the qualities of the grains or the cements which make them. Concerning these grains and these cements I have already given interesting information.

Density.—The part *D*, proceeding from the unattacked brick, gives for apparent density 1·75, and for absolute density 2·40. The brown part *E* has for apparent density 2·15, and for absolute density 2·52. The part *F* has apparent density 2·17, and absolute density 2·45. Examined under the microscope, the grey and brown parts present a complete transformation of the silica into cristobalite and tridymite. The principal material which serves for making these bricks is a quartzite which after complete transformation has an absolute density of about 2·33. The absolute density 2·52, observed in the brown part, is due to the quantity of iron oxide and other foreign oxides which meet there; in the grey part the quantity of these oxides is less, and the absolute density 2·45 is lower than that of the brown part; these oxides in reality, and in particular iron oxide, have a density higher than that of silica.

Porosity.—The part *D*, corresponding to unattacked brick, has porosity 10·5, the brown part *E* 2·1, and the grey part *F* 0·3. It is seen that this last is more compact than the brown part, though its absolute density is less; this is because it contains more silica and less foreign oxides denser than silica.

Resistance to Crushing at Ordinary Temperature.—(1) The unattacked part *E* resists a pressure of 165 kilog. per sq. cm. (2) The brown part resists a pressure of 1,115 kilog. per sq. cm. (3) The grey part resists a pressure of 1,415 kilog. per sq. cm. The resistance to crushing of the unattacked part *E* is normal for a silica product, though it is a little weak. But the resistance of the materials *E* and *F* is far superior to that of all refractory ceramic products in use till to-day—clays, bauxites, corundums, chromites, magnesias, etc.

Resistance to Crushing at 1,500°.—(1) The part *D* resists a pressure (or load) of 37 kilog. per sq. cm. (2) The brown part *E*, though its fusion point is inferior to that of the preceding, resists a load of 52 kilog. per sq. cm., thanks to its low porosity. (3) The grey part *F* resists a load of 138 kilog. per sq. cm. This resistance under load at 1,500° is superior to that of all other refractories known and tried till to-day, carbon excepted.

According to these experiments it can be inferred that, in the arches of the Martin furnaces, two new materials are formed; a brown product and a grey product of which the crushing resistance increases in such proportions that it improves the quality of the original product employed; this remark applies chiefly to the grey part.

3. *Micrographic Studies.*—The brown part *E* presents under the microscope an abundant formation of tridymite crystals; in the midst of the black mass a copious quantity of free silica exists. The grey part *F* has a very different crystallographic composition; it presents a microgranular mass, probably of cristobalite, which no longer acts on polarised light.

Conclusions.—The results of this study indicate the influence of density and porosity on crushing resistances; they give valuable indications as to the condition of the bricks in the Martin furnace and the essential principles which should be observed in the management of these furnaces. Finally they demonstrate two very plain facts, contrary to the opinions generally approved at this moment: (1) It is admitted that silica products are only of good quality if they include 94 to 95 per cent. of silica. But my experiments show that the grey parts of the bricks, which contain only 85 per cent. of silica and 15 per cent. of foreign matters, are as refractory as products with 95 per cent. of silica, and that thanks to their feeble porosity, they are far superior as regards crushing resistance at all temperatures. (2) It is equally admitted that an excess of lime and of iron oxide is detrimental in silica products, and that it is only necessary to exceed the proportion of 3 to 4 per

cent. for these two elements combined. But in the grey part of the bricks the proportion of these two elements varies from 10 to 14 per cent.

These observations confirm the results which I have already found otherwise in my study on the constitution of enamelled silica bricks from the frieze of archers at the palace of Darius, executed 500 years before the Christian era, and which are in the Louvre Museum. These bricks contain about 11 per cent. of foreign matters (other than silica), and do not melt before 1,730°.

The following table recapitulates some of the physical tests which have been made in the course of these studies.

A. Brick of good quality. Fig. 1.

B. Brick which cracks at high temperature. Fig. 2.

C. Brick made with rocks friable at high temperature.

D. Brick from a Martin furnace, unattacked part. Fig. 3.

E. Brick from a Martin furnace, brown part. Fig. 4.

F. Brick from a Martin furnace, grey part. Fig. 5.

	A	*B*	*C*	*D*	*E*	*F*
Fusion Point	1750°	1730°	1730°	1730°	1710°	1730°
Linear expansion at 1710° (per cent.)	1·60	5·90	4·00	2·50		
Porosity (Water absorbed, (per cent.)	12·0	9·5	10·0	10·5	2·1	0·3
Porosity after heating at 1710° (per cent.)	9·7	16·1	12·0	9·0		
Crushing resistance at ordinary temperature	121	480	160	166	1115	1415
Crushing resistance at ordinary temperature after heating at 1710°		nil	52			
Crushing resistance at 1500° after heating at 1710°	77	nil	nil	37	52	138

The crushing resistance is expressed as kilog. per sq. cm.

Appendix II.

Measurements of the Crushing Resistances of Refractory Materials.

Method of Captain V. Bodin.—The crushing resistance of refractory materials, at various temperatures, is of considerable industrial interest. Some years ago a certain number of scientists made experiments on this subject. In 1910 Gary observed that the crushing resistance of refractory products

increases up to about 1,000°. According to Gary, a refractory brick, resisting 169 kilog. per sq. cm. at ordinary temperature, attains at 1,000° a resistance of 218 kilog. per sq. cm. Since that time Dr. J. W. Mellor has published several series of experiments made in this subject. More recently M. Le Chatelier, resuming his study on industrial products, published various interesting results on refractory products with a basis of silica, magnesia, etc. According to the studies of these scientists the crushing resistances go on decreasing by degrees up to about 1,500° to 1,600°, according to a fairly regular curve.

Two years ago I was asked by Guerineau & Co. to study the question of the crushing resistance at various temperatures of their refractory products. I had an apparatus constructed adaptable to my recuperative furnace; tests of crushing resistance, at various temperatures, were made on small cubes (25 mm. side) of refractory materials. My method being too slow I submitted the question to Captain V. Bodin, Head of the Materials of Construction Section at the testing laboratory of the Conservatoire National des Arts et Métiers. Captain Bodin got the idea of employing Frémont's machine for these measurements and invented a special contrivance for recording the pressures at the moment of crushing. The refractory products to be tried are prepared in the form of small cubes of 20 mm. side, carried to the temperature at which it is desired to operate; they are placed in a gas-heated furnace, between two cylinders of refractory materials, very resistant to crushing. The temperature of the furnace, in the immediate vicinity of the test cube, is measured by a thermo-electric couple (Le Chatelier).

The successive operations are performed on a dozen cubes of each material at various temperatures up to 1,500°, and then for each material an exact curve is obtained. From numerous tests, performed up to this day, it follows that refractory products can be classed in two categories: (1) Those of which the crushing resistance presents a maximum at about 1,000°. (2) Those which do not present a maximum. In the first category must be ranged kaolins, clays, bauxites, silica products, products with carborundum as basis, etc. In the second category should be placed products of chromite, Eubœan or Styrian magnesia, etc. The curves below are related to the principal refractories tried. The curve, figure 6, is that of a silica brick. 7 is that of a refractory clay from Provins. 8 is that of a white bauxite. 9 is that of an agglomeration of carborundum.

In the second category are ranged refractory oxides such as magnesia, chromite, etc. The curve figure 10 is that of

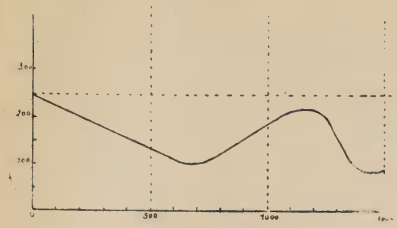


Fig. 6.

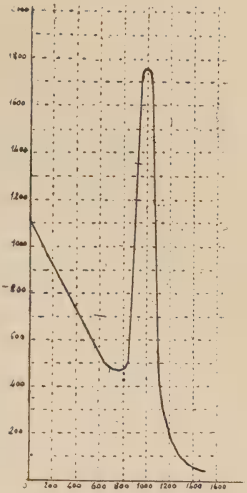


Fig. 7.

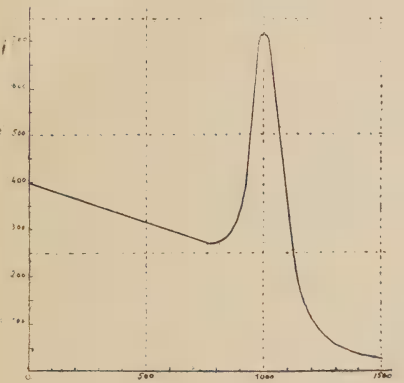


Fig. 8.

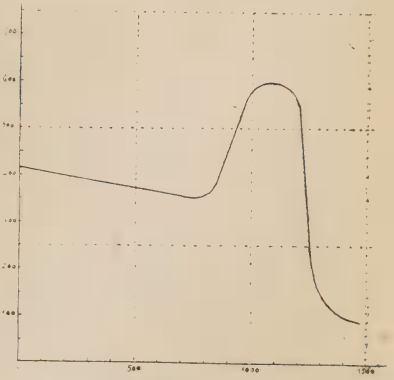


Fig. 9.

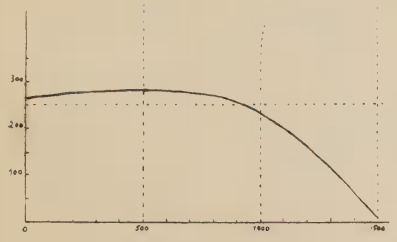


Fig. 10.

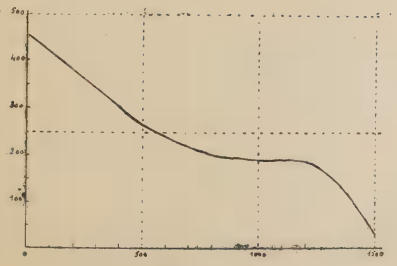


Fig. 11.

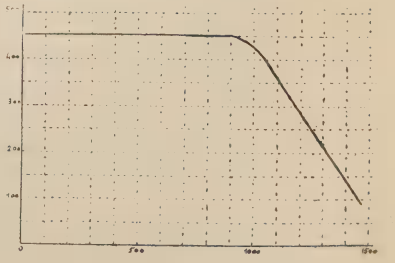


Fig. 12.

Eubœan magnesia. 11 is that of Styrian magnesia. 12 is that of a chromite product. The numbers inscribed under the vertical lines express the pressure in kilog. per sq. cm. The points on the abscissæ express the pressure in kilog. per sq. cm. The points on the ordinates denote the temperatures at which the tests have been made.

With the refractory products which present a maximum at about 1,000° the crushing is done in two ways according to the temperature of the test. Until the culminating point is a little exceeded the material is crushed and ground to bits; in the descending part of the curve the material is flattened and behaves partly or wholly like a plastic substance; among the various products which were submitted to these crushing tests only one does not soften, and is crushed to bits plainly at 1,500°; this is the grey substance *F* (of Appendix I) from bricks which have been in the arches of the Martin furnaces.

The increase of crushing resistance about 1,000°, which characterises a great number of refractory materials, has not been explained until this day; it depends at first sight on neither the chemical nor the mechanical composition of these materials. It is necessary, I believe, to seek the explanation of it in a fact observed by Messrs. C. Edwards and A. Rigby, and described in an article which Dr. J. W. Mellor published in the TRANSACTIONS of the Ceramic Society (**16**, 271, 1917) on the coefficient of expansion of refractory products.

From these experiments it results that the coefficient of expansion decreases between 900° and 1,200°; an ordinary refractory brick, carried from 15° to 940°, has for average coefficient of expansion 0·0000081, and the same brick between 15° and 1,180° has for average coefficient of expansion 0·0000061; the same phenomenon is produced with silica bricks. It is possible that this decrease of the coefficient of expansion, in the vicinity of 1,000°, provokes in these materials a sort of contraction which makes them more compact and increases their crushing resistance. This statement would be easy to verify by repeating the experiments of Messrs. C. Edwards and A. Rigby on the principal refractory products which I have tried. If my explanation is correct, refractory products like magnesia, chromite, etc., which do not exhibit increase of resistance about 1,000°, should not at this temperature have a decreasing coefficient of expansion. The supports of the trial cubes should resist high temperatures without being deformed or broken. The best supports, permitting the tests to be made in ordinary practice, do not resist beyond 1,500°; but it is certain that supports will soon be available to permit operations being carried out at temperatures above 1,500°. The experiments have been

performed on small cubes 2 cms. side; but I see the possibility of soon carrying out these measurements on more important pieces, either whole bricks or half-bricks.

Although this may only be the beginning of this study, it can be considered that Captain Bodin's method constitutes a real progress, and that it will have a great influence in the manufacture of refractory materials. In reality for the same product the curves are very variable according to its mechanical composition and according to the temperature to which it has been burned; but the curves furnish valuable indications as to the processes of manufacture to be adopted. The denomination "Refractory Products" is a very vague expression until to-day, for with these products account has only been kept of their alumina content and their fusion point. But a good number of refractory products do not contain alumina, and the present method for the fusion point is insufficient. Determination of the curve of crushing resistance, at various temperatures, furnishes a very interesting new datum which can be introduced into the clauses of the specification.

IX.—On the Standardization of Chemical Stoneware.

By HARALD NIELSEN.

Introduction.

WHEN my friend Mr. Garrow and I set out about a year ago to write a short series of articles, or rather suggestions, towards standardization of chemical stoneware in the *Chemical Trade Journal and Chemical Engineer*, we hoped that it would create some interest in certain circles, but we never thought that the correspondence column in the *Chemical Trade Journal* would receive so many letters to the Editor regarding this subject and voicing such a number of opinions—chiefly favourable—mostly from large chemical pottery firms, as it did.

It showed to our minds very clearly that something of the kind was urgently wanted, and, that once started, the standardization movements would quickly assume the proper proportions.

To-night I shall have the honour to lay certain suggestions before you, gentlemen, with the object in view of starting a discussion, so that the final British standardization of chemical stoneware may not be the work of one or two men, but the work of a great number of men, criticised and improved by manufacturers and users alike. This is the only way I can see towards perfection, and I trust that some of the few suggestions I make can serve as a base or foundation on which more capable hands than mine can erect the building.

I hope that the discussion will not be too technical as far as the chemical composition and mixing of various clays, etc., is concerned, as this is somewhat outside the frame of this paper, and secondly, I must admit that I do not know sufficient about the chemical side of the manufacture of stoneware to understand such discussion, let alone take part in it; I am only a chemical engineer, and am chiefly concerned about the practical side of the thing, that is to say, the use of chemical stoneware for chemical plants, and how it to the best of my knowledge can be properly adopted for that purpose, and secondly, to try to get chemical pottery plants designed on general engineering lines. The greater part of chemical stoneware plant has,

to my mind, far too long been on the same lines of design as laboratory glass apparatus, only multiplied by 10, 20 or 100 as the case may be. It is clear that this is not the best way to go about this business, I think it stands to reason that before a plant can be expected to give the highest efficiency it must be built on the right principles; this applies to all chemical plants, and especially stoneware.

In stoneware, when properly made, we have a cheap and splendid material which stands the most corrosive alkaline or acid fluids and gases a hundred times better than any metallic alloys. The raw material is here, and the United Kingdom is particularly favoured with such material, as all of you gentlemen know far better than I do. It is up to us to bring this raw material into proper shape, so that it can successfully compete with silica and metallic alloys for all purposes where these are used.

I do not think that I am wrong in stating that the heavy chemical and a great part of the fine chemical industry was first initiated in this country, consequently the demand for suitable stoneware was first felt here. Gradually the German industry came into existence with its demand for stoneware, and eventually, after much research, they got huge works set going which turn out splendid chemical stoneware, more than sufficient for their own consumption, and then the deluge came, the American papers were full of advertisements for real genuine imported German pottery, and this country of course also received its share.

In order to smash all opposition and drown everybody the German chemical stoneware manufacturers made a ring, standardized their clay mixtures and sold at controlled prices. Meanwhile they were busily booking orders all over the world, and tried to get everybody drilled into using their material; they were willing to make all sorts of shapes and designs to suit the individual chemical manufacturer's taste until they thought they had the market in the hollow of their hand. Then they gently set about to let the chemical manufacturers feel their will. They standardized the most commonly used apparata, thereby saving labour and reducing the cost of manufacture enormously, and told the chemical manufacturer, next time he sent them his fancy design, that they of course would make it for him, but the cost would be great, and the time of delivery long, but on the other hand they had a standard article, which they could deliver direct from stock and so on. The manufacturer, being a business man, naturally took what was offered and was pleased; the Germans were pleased too, they had managed to sell just what they wanted to sell. They

carried the standardization further and further, I do not know how far they have gone, as, owing to the war, I have not been able to keep track of the latest developments; anyhow they have doubtless reaped the reward of their system and organization. It seems to me, that although I do not quite agree with the German way of carrying out trade campaigns, there is much commonsense in their methods in this particular line. The chemical works are, as a rule, run by chemists, and it is not to be expected that they should know as much about engineering principles as about chemistry. They should have somebody to think for them regarding plant design. The German stoneware engineers did the thinking and supplied a standard article, properly designed and suitable for the purpose in view, to the vast mutual benefit of the chemical manufacturer and themselves of course.

Before we begin to talk about forms and shapes of standard pieces it might be interesting to look at a typical example of a chemical plant, for instance, the condensing and absorption part of a modern nitric acid plant, such as is used for the manufacture of strong nitric acid for high explosives, etc.

Fig. A shows such a plant, and also illustrates many typical pipes, etc., and how the various stoneware pieces are put together. This should enable us the better to understand the pieces we are about to discuss in detail later on.

The hot nitric acid fumes coming over from the still are cooled down in an air cooler made up from ordinary wide socketed low pressure pipes and bends, connected at the bottom by means of two-neck jars, which also act as containers for any condensate.

From the air cooler the fumes enter the first cooling and absorption tower, which is made from large-bore socketed pipes, and is filled with a filling material in order to present a large wetted contact surface to promote cooling and absorption of the fumes. The hot condensate, together with the heated circulating acid, runs from the bottom part of the tower through a stoneware cooler which is placed in a narrow water-filled box; here the acid is cooled down to the temperature desired, and runs into a large collecting jar, which feeds an acid egg or pressure vessel (also called Monte-Jus). When the acid egg is full, the cock between this and the collecting jar is shut off and compressed air is let into the egg, thereby forcing the acid through the vertical pressure pipes up to the smaller jar on top of the tower. From here the acid is by means of a distributor equally sprayed over the transverse section of the tower, descending and moistening the filling and reacting with the fumes. The acid is circulated up and down

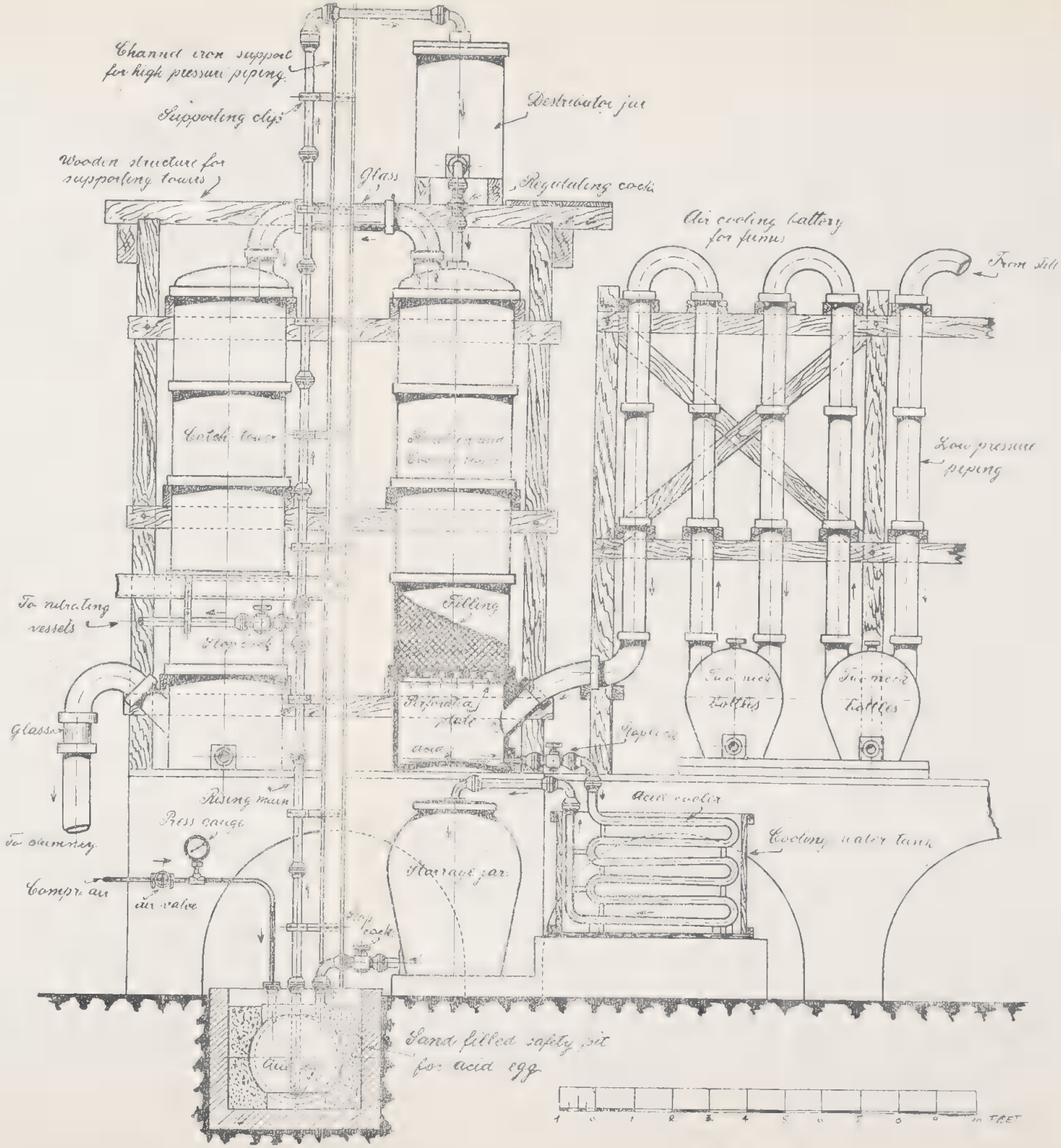

Channel iron support for high pressure piping
Supporting clip
Distributor jar
Wooden structure for supporting towers
Glass
Regulating cock
Air cooling battery for fumes
From Still
Low pressure piping
Catch tank
To nitrating vessels
Stop cock
Filling
Glass
To chimney
Rising main
Press gauge
Compr. air
Air valve
Stop cock
Storage jar
Acid cooler
Cooling water tank
Sand filled safety pit for acid egg
1 0 1 2 3 4 5 6 7 8 9 10 FEET

Fig. A.

until it reaches the necessary strength, it is then by means of the branch pipe, shown on the rising pressure pipe, sent to the concentrating plant, or if strong enough, directly to the nitrating vessels. Whilst the acid is circulating, the fumes are continuously coming forward in counter current to the acid and leaving the top, afterwards entering a second tower similar in construction to the first. In the second tower the last traces of nitric acid are caught before the exhausted fumes are led into a chimney.

During the whole of this operation the acid and the fumes have not been in contact with anything else but stoneware. The fumes and acid being highly corrosive, it is clear that only the best and most carefully manufactured stoneware can be used with satisfaction. Generally the pressure of the fumes is slight, only an inch of water-column at the most, but the penetrating or diffusing power is great, and, if sweating is to be prevented, the thin walled pressure pipes and towers must be thoroughly vitrified, and the glaze should on no account be solely relied upon to resist the penetrating power of the fumes.

You will see from the drawing that when we come to the acid piping we are no longer using socketed joints, as it has been found from experience that these are not very suitable for liquids under pressure. We must here use proper ground flanged joints (I shall go more into details of these later on), especially when high pressure is concerned, say, for instance, 60 lbs. per sq. inch.

Now in the present case we have to pump acid from the acid egg up to the top of the tower, the distance being say 30 feet, and when the specific gravity of the acid is 1·30 we must have an air pressure of at least 20 to 22 lbs. per sq. inch.

If the pumping height be greater, correspondingly higher pressure is wanted, for example, a Gay-Lussac tower with a total pumping height of 60 feet and using sulphuric acid of 1·60 specific gravity, would require 48 lbs. per sq. in. pressure.

It is clear that, if the acid egg and pressure piping shall withstand this high pressure, it must be of the densest material.

Great care must be taken in the manufacture and erection, as careless workmanship in any shape or form will not only place the whole plant in jeopardy, but will entail great danger to the people who are running it. I have seen workmen frightfully burnt and permanently blinded, and I have received very unpleasant splashes myself, so I am well aware of the serious risks incurred when the chemical stoneware is not absolutely faultless and up to specification in every detail.

But to come back to the drawing, every piece of stoneware used is of as simple a design as possible and can be of standard design. You will readily understand that if a British standard system of dimensions had been evolved before the war the explosive position would have been immensely easier. Various works could have concentrated on special plant such as pipes, tanks, stop-cocks, etc., for which they were best placed, and the plant would then have been quickly delivered in the huge quantities required.

Replacements and spares would have been an easy matter, as all makers throughout the country would have been working to the same standard dimensions, and all makes would have been interchangeable and no unreasonable delay would have occurred. The labour question would have been easier, as fewer people would have been required for pattern- or mould-making, etc.

As to what really took place, I think that some present may know more than I do. Numbers of people took up the explosive manufacture who had little or no previous experience in the matter at all. They all started designing pottery plant of which they knew still less, and the stoneware manufacturers were inundated with drawings and designs, many of them impossible to carry out in practice. All these fancy designs required new patterns and moulds, a large number of skilled people to make them, and much time and trouble was wasted at a time when every hour counted.

That the position did not get worse was first and foremost due to the British potters sticking to the job in spite of serious shortage of labour and of necessary machinery which could scarcely be procured at any cost, and the worry of trying to manufacture goods such as had never been made in this country before.

Nevertheless, I think we have all of us learnt the lesson now. The Germans were ready in this particular line before the war: it is up to you gentlemen to carry on and to see that you get your shot in first now the war is over and reconstruction goes forward. The way to do it is to standardize everything which can profitably be standardized.

You will benefit by having a greatly reduced number of patterns to make; you will become experts by repeating the same pattern constantly, and the necessary spare pieces will be a source of trouble no longer. The user will benefit by being able to buy from any maker, knowing that all makes are of the same dimensions—*standards*—he can get quick delivery at lower costs, and can select the class of stoneware most suited for any specific purpose. And he will no longer

worry himself and *you* with the fancy impossible designs of earlier days

Resume of Suggested Standards.

The plant which first of all suggests itself for standardizing is naturally stoneware pipes with their various most commonly used accessories, such as bends, T-pieces, cocks, etc., and I think it is just as well at once to make a sharp distinction between pipes to be used for high pressure and liquids, and pipes to be used for low pressure and fumes only. The first mentioned have come much to the fore lately as new and modern chemical industries and processes crop up every moment, where it is necessary to deal with volumes and pressures of corrosive matters never thought of before, and I shall deal with these first.

During 1911 and 1912 I was on the Continent engaged on the erection of a large chemical plant for an English concern. We wanted high pressure stoneware pipes, and as nothing suitable was to be had from this country at the time, we had to go to Germany for them. The order was a large one, several thousand pounds and, needless to say, the German firm who secured the order did all they could to please us. The result was a plant which at that time was regarded as unique as far as the stoneware plant was concerned. All the dimensions of the pipes were standard, and somewhat similar to those which I shall presently have the pleasure of laying before you. The plant stood excellently for several years until the German army took possession of the place. The standards I should suggest are slightly heavier than the German, as I think it will be some time yet before every potter in this country will use a standard raw material of uniform high strength such as the German material. There are many potters whose material does not come quite up to the highest tensile strength, therefore in my opinion due regard should be paid to those, and the standard made such, so that the pipes are strong enough to carry the rated pressure with an ample safety margin when made from this latter material. I should further suggest that if a potter possesses a raw material which, when burnt, gives a stoneware of superior strength, he should not diminish the wall thicknesses, but his pipes should be allowed to be used for higher pressures than the other pipes; how high should be determined by proper experts, and sample pipes tested from time to time to make sure that the material is uniform.

In a recent series of articles by my friend Mr. Garrow and myself in the *Chemical Trade Journal* we said that the

ultimate tensile strength of high class English vitreous stoneware seems to vary between 600 and 800 lbs. per sq. inch, and material below this should not be used for chemical plant under pressure.

As far as the actual calculation of stresses in a stoneware pipe, subjected to internal pressure, very little research has to my knowledge been carried out. Some people suggest that the formula applying to thick-walled iron hydraulic pressure pipes should be used as the wall thickness of the stoneware pipe is comparatively large in proportion to the diameter, but they forget that stoneware is not steel or cast iron, and the structure is entirely different. It has even been found recently that the hydraulic formula for steel does not apply to cast iron, and I venture to say they will in all probability be further off when it comes to stoneware, but whether on the side of safety or otherwise I do not know.

I have, however, found that a stoneware pipe calculated according to the simple formula: $w = \frac{p \times d}{2 \times u}$ where w = wall thickness in inches, p = pressure in lbs. per sq. inch, d = diameter in inches, u = ultimate tensile strength in lbs. per sq. inch, will stand the pressure required within the limits of u, and, as stoneware is practically a non-elastic body, I think that I am justified in employing this formula as the base of the pipe standards. It stands to reason that for a material which is subjected to pressing or moulding, drying, burning and cooling, whereby all sorts of stresses might be set up, the working safety margin should be reasonably large, and I suggest 4 as the factor by which the w found by the formula should be multiplied. In practice I have found this to answer very well.

I am of opinion that high pressure stoneware pipes of above 4 inches diameter should be avoided, partially because the wall thickness becomes rather heavy and drying difficult, and the chances of successful vitrification thus decreases. The wall thickness for a 4 inches pipe of standard size is 1 inch. If a larger amount of liquid than a 4-inch pipe will transmit is to be dealt with two or more separate 4-inch pipelines would meet the case with far greater safety; besides, one line could always be used as a spare in case of a breakdown, so as not to have all the eggs in one basket, as would be the case with a 6 inches or 8 inches pipe.

I cannot think of a more suitable flange-joint to suggest than the conical buttressed flange, first of all because the increase in material is very gradual, which every practical potter will appreciate; secondly, it is much stronger and not

easily broken off, and thirdly, it lends itself in conjunction with a suitable iron clamp most excellently for joining up and fixing and gives a certain amount of flexibility as well.

The French and German people used straight or flat flanges as on iron pipes to begin with, but they have gradually discarded them for the conical flanges when they woke up to the virtues of these.

The French potters are fond of a cone tapering very much more than these which I would suggest; I do not agree with them, because a taper cone sets up heavy stresses in the iron clamps, the more the taper the heavier being the stresses, of course due to the wedge action, and I have seen these clamps burst right across during the tightening up of the joint before the pipes were under pressure.

I would suggest that the angle of the cone should be 30° with the centre line of the pipe, this would be quite sufficient to avoid any manufacturing or erecting drawback and would not cause too great a stress on the iron clamps.

Fig. 1 shows the standard pipe with conical flange, and Fig. 2, *a*, *b*, *c*, the iron clamp, which should preferably be made in malleable iron. Table I gives the dimensions for standard high pressure pipes from 1 inch diameter up to and inclusive 4 inches diameter, and Table II, *a*, *b*, *c*, the dimensions for the malleable iron clamps or flanges.

It is suggested that the straight pipes are made in standard lengths from 6 inches—1 foot—1 foot 6 inches—2 feet—2 feet 6 inches and 3 feet, and by special request 4 feet and 5 feet.

With reference to bends, T-pieces (equal or unequal), cross pieces, these should of course have the same dimensions as straight pipes as far as wall thickness and flanges are concerned, and I should suggest from a practical point of view that, for the same bore, all branches should have equal dimensions; for instance, if a pipeline contains a right-angle bend, it is very often desirable to substitute a T-piece or a cross piece; when the dimensions are equal this can be done without interfering with the rest of the pipeline. A cock should also have the same overall length as the T-piece of same bore, besides being straight through flow, whereby loss in pressure due to friction is greatly diminished.

The overall length of such a T-piece, etc., should in my opinion be governed by a right-angle bend of the same bore; it is clear that in order not to lose too much pressure due to friction or obstruction caused by whirls and eddies in the liquid conveyed the radius should be as large as can conveniently be tolerated. A formula very much in vogue on the Continent, and one which has given general satisfaction, is the following:

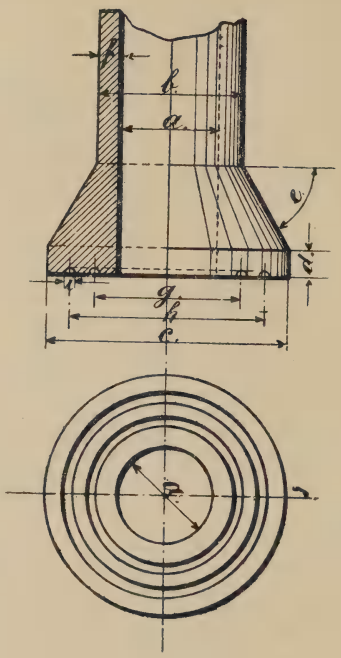


Fig. 1.

TABLE I.

a Ins.	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*
1 ...	1·60	3·50	0·30	60°	0·30	1·75	2·50	0· 0
1½ ...	2·30	4·25	0·40	60°	0·40	2·40	3·25	0·10
2 ...	3·00	5·00	0·50	60°	0·50	3·00	4·00	0·125
2½ ...	3·70	5·75	0·50	60°	0·62	3·70	4·70	0·125
3 ...	4·50	6·50	0·50	60°	0·75	4·50	5·50	0·125
3½ ...	5·25	7·25	0·60	60°	0·87	5·25	6·25	0·125
4 ...	6·00	8·00	0·60	60°	1·00	6·00	7·00	0·125

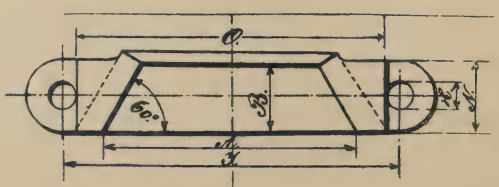


Fig. 2a.

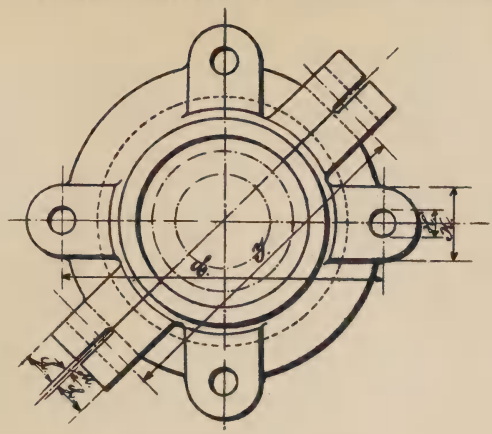


Fig. 2b.

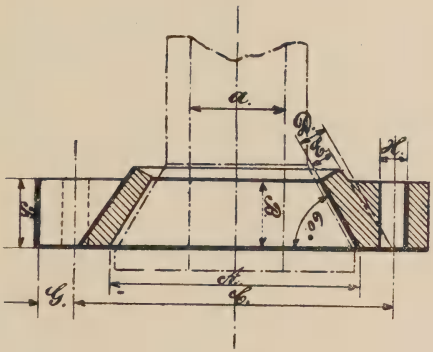


Fig. 2c.

TABLE II. (*a*—*b*—*c*).

a	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*K*
Ins.								Ins.		
1 ...	3·75	1·35	5·00	0·45	0·35	1·20	0·60	$^{7}/_{16}$	5·40	1·20
1½ ...	4·50	1·40	5·80	0·50	0·40	1·30	0·65	$^{9}/_{16}$	6·20	1·30
2 ...	5·25	1·45	6·60	0·55	0·45	1·40	0·70	$^{9}/_{16}$	7·00	1·40
2½ ...	6·00	1·50	7·40	0·60	0·50	1·50	0·75	$^{11}/_{16}$	7·80	1·50
3 ...	6·75	1·60	8·40	0·65	0·55	1·60	0·75	$^{11}/_{16}$	8·80	1·50
3½ ...	7·50	1·70	9·40	0·70	0·60	1·70	0·85	$^{13}/_{16}$	9·80	1·70
4 ...	8·25	1·80	10·40	0·75	0·65	1·80	0·85	$^{13}/_{16}$	10·80	1·70

a	*L*	*M*	*N*	*O*	No. of Bolts I.	Diam. of Bolts I. & II.	Length of Bolts I.	No. of Bolts II.	Length of Bolts II.
Ins.						Ins.	Ins.		Ins.
1 ...	0·5	0·125	1·20	4·80	4	$\frac{3}{8}$	$3\frac{1}{2}$	2	$1\frac{1}{2}$
1½ ...	0·6	0·125	1·30	5·60	4	$\frac{1}{2}$	4	2	$1\frac{3}{4}$
2 ...	0·7	0·125	1·40	6·40	4	$\frac{1}{2}$	$4\frac{1}{2}$	2	2
2½ ...	0·8	0·20	1·50	7·20	4	$\frac{5}{8}$	5	2	$2\frac{1}{2}$
3 ...	0·8	0·20	1·50	8·20	4	$\frac{5}{8}$	$5\frac{1}{2}$	2	$2\frac{1}{2}$
3½ ...	1·0	0·20	1·70	9·20	4	$\frac{3}{4}$	6	2	3
4 ...	1·0	0·20	1·70	10·20	4	$\frac{3}{4}$	6	2	3

$l = d + 4$ inches, where l = distance from flange to centre line of piece, d = internal diameter.

I do not see why this formula should not give equal satisfaction for stoneware, and I have therefore computed Table III, *a*, *b*, *c*, *d*, on the basis of this.

The centre distance for an unequal branch ought to be taken with regards to both bores, and I think that the following suggestion is the easiest and simplest way out of the difficulty, namely: $l = (\frac{d_1 + d_2}{2}) + 4$ inches.

Fig. 3, *a*, *b*, *c*, *d*, show a 90° bend, a 45° bend, an equal T-piece and an unequal T-piece.

For the purpose of facilitating the erection of a pipeline between two fixed points a short cylindrical piece of the same outside diameter as the conical flange corresponding to the bore will be found extremely useful. The distance piece should be supplied in the following lengths: ½ inch, 1 inch, 2 inches, 3 inches, 4 inches and 5 inches, any odd fraction of an inch can easily be produced by grinding the next size down. In this manner it will be clear that it is possible to erect a pipeline with any exactitude desired.

Blank flanges for closing the free end of a pipeline can be formed as solid conical flanges of the exact dimensions corresponding to the flanges of the bore of pipeline in question. This will be perfectly clear without further comment.

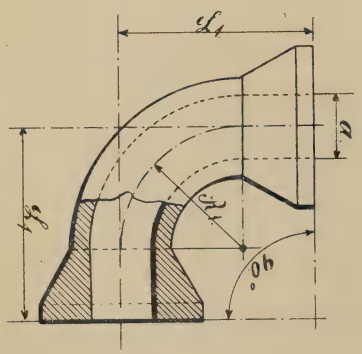


Fig. 3a.

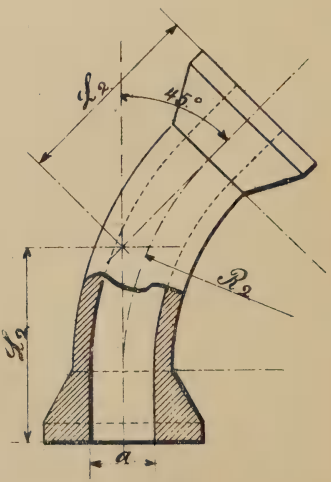


Fig. 3b.

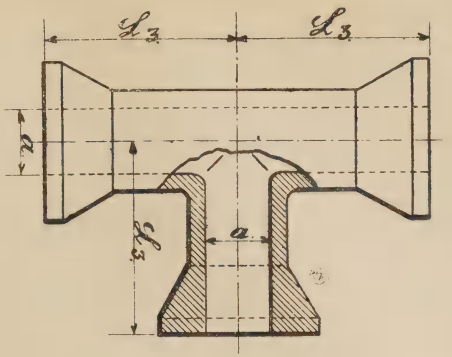


Fig. 3c.

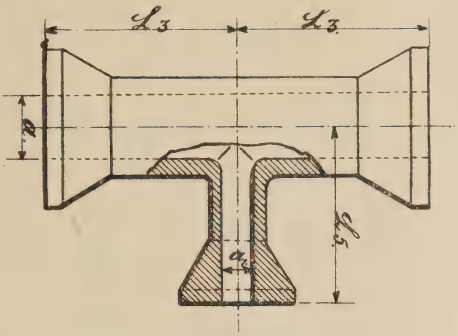


Fig. 3d.

TABLE III (a—b—c—d).

a Ins.	L_1 Ins.	R_1	L_2 Ins.	R_2	L_3 Ins.
1	5	3·00	5	7·50	5
1½	5½	3·375	5½	8·50	5½
2	6	3·75	6	9·50	6
2½	6½	4·125	6½	10·50	6½
3	7	4·625	7	11·50	7
3½	7½	5·125	7½	12·50	7½
4	8	5·625	8	13·50	8

a Ins.	a_1 Ins.	L_5	a_1 Ins.	L_5	a_1 Ins.	L_5	a_1 Ins.	L_5	a_1 Ins.	L_5	a_1 Ins.	L_5
1	—	—	—	—	—	—	—	—	—	—	—	—
1½	1	5·25	—	—	—	—	—	—	—	—	—	—
2	1	5·50	1½	5·75	—	—	—	—	—	—	—	—
2½	1	5·75	1½	6·00	2	6·25	—	—	—	—	—	—
3	—	6·00	1½	6·25	2	6·50	2½	6·75	—	—	—	—
3½	1	6·25	1½	6·50	2	6·75	2½	7·00	3	7·25	—	—
4	1	6·50	1½	6·75	2	7·00	2½	7·25	3	7·50	3½	7·75

I mentioned above that a stop-cock ought to have the same overall length as a T-piece of the same bore; another thing to which I should like to draw attention is the taper of the plug. The taper should not be too gradual, as the plug then becomes liable to stick in the casing and may easily break off; on the other hand it must not be too quick, because the plug is then more liable to blow out unless a safety bridge is arranged to keep it in position.

This safety device should never be omitted when corrosive and dangerous liquids are carried through the pipeline or any liquid under pressure. A stop-cock plug taper which I have found very suitable is with the angle whose tangent is 0·05; to this corresponds roughly an angle of 2·8 to 3 degrees.

Naturally the design of a stop-cock ought to be as simple as possible, as simplicity spells efficiency in this case even more so than in most.

As a guide to the principal dimensions I would suggest that they be all made simple expressions of the bore or wall thickness and outside diameter, for example:

b = bore $a + 2 \times$ wall thickness f

$m = b - (u \times 0{\cdot}1)$	$s = q + 0{\cdot}50$ inch
$n = m + (2 \times f \times 1{\cdot}5)$	$t = b + 0{\cdot}50$ inch
$o = b + (u \times 0{\cdot}1)$	$u = b + 0{\cdot}875$ inch
$p = o + (2 \times f \times 1{\cdot}5)$	$v = \frac{1}{2}b + 0{\cdot}25$ inch
$r = q \times 3$	$w = \frac{1}{2}b + 0{\cdot}50$ inch

As an example Fig. 4, *a*, *b*, is a 2-inch stop-cock constructed according to above specification, which I have found answers very well for all practical purposes, as it gives a stop-cock which is not clumsy, but still is of ample strength.

For stop-cocks of large bore the plug should either be strengthened by means of a web across the bore, or the hole can be made oval, the small axis being say two-thirds of the large axis, in any case the area should be as near as possible the same as the area of the bore.

It is not the object of this paper to go too much into constructional details, so I think I may leave the high pressure piping with just some few words about the erection.

It will be clear from the illustration referring to the high pressure piping that we are now advancing on engineering lines proper, and that the assembling cannot very well be trusted to unskilled labour. A mechanic or iron pipe fitter would here be the right man, as the joining up of these pipes much resembles the joining up of flanged iron piping. I have found from my own experience that only a responsible,

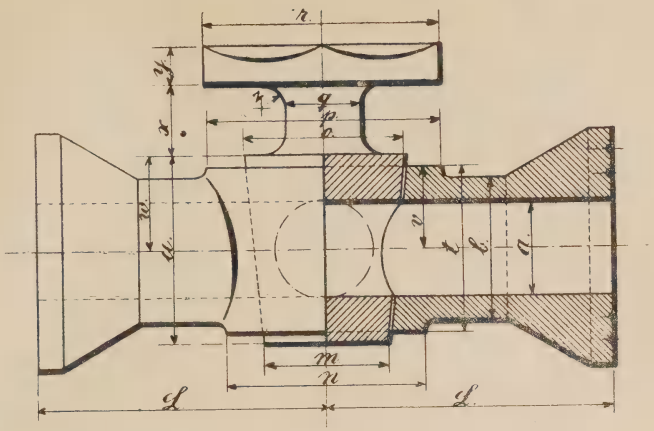


Fig. 4a.

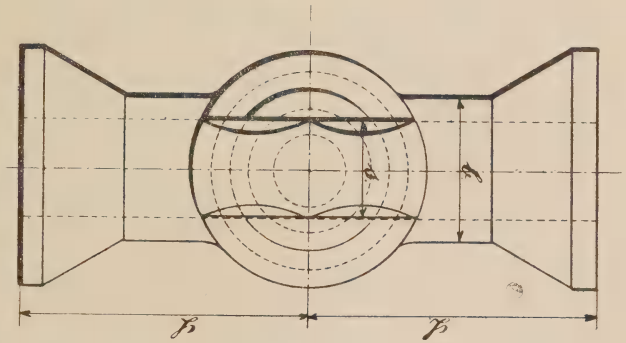


Fig. 4b.

TABLE IV. (*a*—*b*).

a	*b*	*L*	*m*	*n*	*o*	*p*	*q*	*r*
Ins.								
1	1·60	5·00	1·35	2·25	1·85	2·75	1·125	3·375
1½	2·30	5·50	1·98	3·18	2·62	3·82	1·25	3·75
2	3·00	6·00	2·62	4·12	3·38	4·88	1·50	4·50
2½	3·70	6·50	3·24	5·08	4·16	6·00	1·75	5·25
3	4·50	7·00	3·96	6·21	5·04	7·29	2·00	6·00
3½	5·25	7·50	4·64	7·25	5·86	8·47	2·25	6·75
4	6·00	8·00	5·32	8·32	6·68	9·68	2·50	7·50

a	*s*	*t*	*u*	*v*	*w*	*x*	*y*	*z*
Ins.								
1	1·625	2·10	2·475	1·05	1·30	1·00	0·50	0·50
1½	1·75	2·80	3·175	1·40	1·65	1·00	0·50	0·50
2	2·00	3·50	3·875	1·75	2·00	1·50	0·75	0·50
2½	2·25	4·20	4·575	2·10	2·25	1·50	0·75	0·75
3	2·50	5·00	5·375	2·50	2·75	2·00	1·00	0·75
3½	2·75	5·75	6·125	2·87	3·12	2·00	1·00	0·75
4	3·00	6·50	6·875	3·25	3·50	2·50	1·25	0·75

intelligent and careful man should be employed; it does not take him very long before he gets the right touch, as the whole question is simple enough when the necessary care is taken.

He must first of all learn that under no circumstances must iron or other metals be in direct contact with stoneware, soft lead excepted; there must always be a soft fibrous material such as rubber or asbestos, millboard or cloth, between the iron clamps and the conical buttress flange before any tightening up can take place; secondly, the proper rigid supporting of the pipeline is of utmost importance, and a heavier steel or wooden joist should be used than that corresponding to the carrying of the weight of the piping. I have generally used joists of eight to ten times the carrying capacity required by the calculations, solely to obtain the rigidity. For instance, the deflection on a 10 feet span should not exceed $\frac{1}{16}$ to $\frac{1}{8}$ of an inch when fully loaded. The supporting joists should never be erected where they can be subjected to vibrations or oscillations from machinery or wind pressure on tall wooden structures.

The pipe-fitter must also remember that each 3 or 4 feet length of piping should be separately supported by a hanger or clip, preferably made from flat iron, say $1\frac{1}{2}$ inch $\times$ $\frac{1}{2}$ inch or $\frac{3}{8}$ inch; further, the clip should be made with bolt holes large enough to allow a slight adjustment once the clip is made to the proper length, and that the clip should be made to suit the pipe and not the reverse, as the pipes must under no account be subjected to any bending stresses.

A soft fibre insertion should always be placed between the pipe and the clip.

Now all the above explanations and instructions sound rather intricate and difficult to carry out, but they are in reality not so, and once the fitter is well drilled into doing the work in the right way, and made to understand that serious trouble will occur if he does not make his job right, the rest is very easy.

A good jointing material is asbestos millboard or thick woven asbestos cloth, thoroughly soaked and boiled in soft paraffin wax, or a mixture of harder paraffin wax with a small percentage of vaseline. The jointing material should be applied as hot as possible, and the buttressed flanges can be heated gently with a blow-lamp in order to retard the cooling down and consequent hardening of the paraffin wax, until the joint is completely made and all bolts are tightened up. Acid-resisting asphaltum can also be used in lieu of paraffin wax, but it is a more troublesome material to deal with. When the pipes should be a permanent job, and no alterations likely to be made, the asbestos packing can be dipped in a strong silica

of soda solution, whereby the pipe joints, so to speak, become cemented together very firmly.

It is a good policy to give the clips such a form, that if any leakages should take place, no dropping of liquid can reach any iron parts.

The ironwork should also receive a good coat of tar after completion, and all smaller parts made from iron, such as flanges, bolts and clips, etc., should be boiled in tar or thin asphaltum for several hours before use.

In order to make a really good, lasting joint, it is of the greatest importance that the flanges should be carefully ground and at right angles to the centre line of the pipes. I shall go further into the all-important grinding question later.

If the work on a pressure pipeline is carried out with care, and in the above mentioned manner, the chemical manufacturer will have the satisfaction of possessing a pipeline which will last him many years, and still give satisfaction long after other pipelines made from so-called acid-resisting alloys have given way.

I think that it will pay an up-to-date stoneware factory to train up one or two men to make a speciality of pipe erection and send them out to erect the piping wherever wanted, and it would pay the chemical manufacturer also to have such a skilled erector supplied with the stoneware. The job would be better and more quickly done than he could hope to do himself, and a certain amount of trouble would be avoided as defects claimed in most cases regarding stoneware plant are generally due to faulty handling much more than faulty material, in which I think that you will agree with me.

Such erectors would be very useful at home at the stoneware factory when no outside erection work is to be done ; they could superintend the grinding, testing cocks, valves, etc. ; in short, they would quickly become past masters in their trade and be a great asset to their employer.

We will now turn our attention to low pressure pipes, by low pressure I should say a pressure which does not exceed one-eighth to one-sixth of an atmosphere per sq. inch, or 4 to 5 feet of water column. The jointing method which naturally suggests itself at once is the socketed joint.

Such pipes should be used for dealing with fumes and gases only, and not liquids, as the jointing would otherwise suffer too much. If any condensation or liquid formation is likely to take place the piping should preferably be placed vertical, or, if necessarily horizontal, should be of the " S " type, or if this is too costly they should be laid under an angle of not less than 30° with the horizontal.

As these pipes have not to stand any pressure which can possibly cause any rupture of the pipes the wall should be made as thin as possible and, in reality, the limit should be strength necessary to stand carriage and handling without any unduly large percentage of breakages.

Thin pipes are quickly dried and generally much better vitrified, that is to say, denser in structure than thicker pipes. If the pipes are used as cooling pipes they will last much longer, as internal stresses due to expansion and contraction during heating or cooling are greatly minimised; besides the conductivity of the actual material is better.

In connection herewith I might mention that my friend Garrow and I are at present conducting exhaustive trials on the question of thermal conductivity of stoneware. The result of these I can say now, without letting the cat out of the bag, will come as a painful surprise to those who pin their faith to so-called acid-resisting alloys as the last word in efficient cooling.

As I think that these researches are outside the object of this paper I shall not go any further into the details, however interesting they are, but we will make them the subject of a paper which we shall have the pleasure of publishing shortly.

I should suggest that the socketed piping is well salt-glazed inside and outside, as loss in pressure due to friction is less, and the finish is better, although on no account should the glaze be relied upon to protect the actual stoneware from corrosion. The stoneware itself should be as resisting as it is possible to make it, and therefore, unless the body itself is thoroughly vitrified, the glaze only gives a false sense of security.

No stoneware plant to my mind is made in such a variety of forms and shapes as socketed pipes and fittings, but there is absolutely no necessity for this. The number of combinations which can be made by intelligent utilization of say one dozen standard shapes is surprising, and quite sufficient for all intents and purposes.

With reference to the standard wall thickness of the pipes a mathematical formula cannot easily be found which will give satisfaction in every case, and I should suggest that the thickness be determined by experience, that is to say, as thin as can conveniently be made and handled afterwards.

The old drain-pipe standard where wall thickness $W = \frac{1}{12} \times d$, d = internal diameter in inches, gives too thin a wall for small bore pipes, and far too thick a wall for convenient drying and subsequent vitrification for large bore pipes, say up to 24 inches diameter. The figures in column f, see Table V (a—g), give

wall thicknesses which I have found to answer very well in practice.

The length L from centre line of bend to face of spigot or bottom of socket is suggested to be the same as under high pressure piping, namely, the inside diameter 4 inches.

The radius R for 90°, 180° and 135° bends can conveniently be: $L-e$, where e = depth of socket. For 45° bends the radius should be: $\frac{L-e}{tg\,a}$ where $a = 45°$.

With reference to 90° branches, the distance h from the socket (outside bottom of socket) to the top of the main pipe can be taken as $h = e + f \pm k$, where e = depth of socket (branch), f = thickness of pipe wall, k = a constant for making up to the nearest $\frac{1}{4}$ inch.

You will readily understand that I have here only mentioned a few of the principal parts of a socketed pipe line, less than the dozen shapes referred to above, as it would take far too long a time to describe the whole of them in details. Fig. 5, *a*—*g*, illustrates the standard pieces mentioned in Table V, *a*—*g*, but I think that the basis of all has been made clear.

It would in my opinion be advisable to form a small commission to finally determine and settle the number and shapes of socketed pipes and the proper dimensions, with a view to meet the demands of the chemical manufacturers and the potters in this particular line.

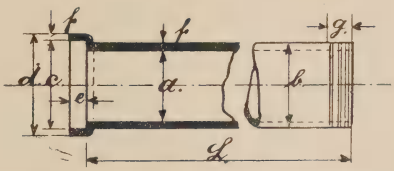


Fig. 5a.

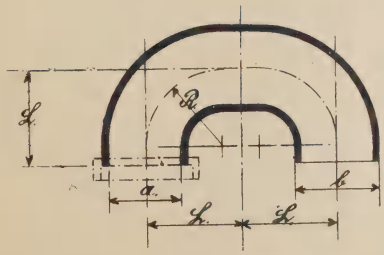


Fig. 5b.

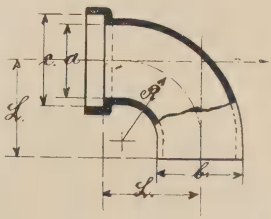


Fig. 5c.

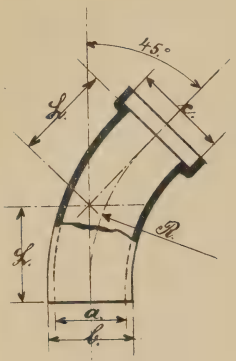


Fig. 5d.

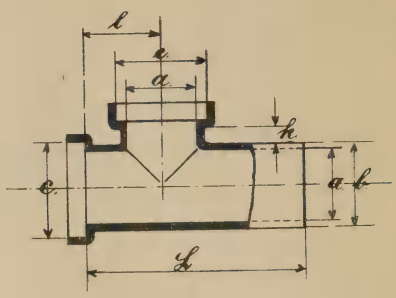


Fig. 5e.

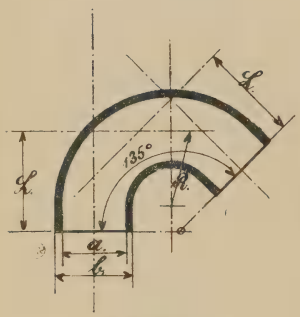


Fig. 5f.

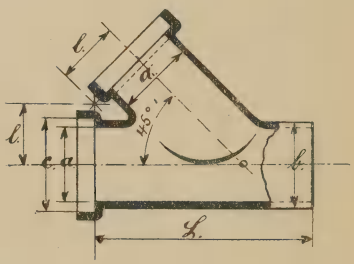


Fig. 5g.

TABLE V. (*a to g*).

										90° & 180° Bends	
a	*b*	*c*	*d*	*e*	*f*	*g*	*L*	L_2	L_3	*L*	*R*
In.							Ft.In.	Ft.In.	Ft. In.		
2	2·50	3·10	3·6	2·00	0·25	2·00	2 6	3 0	4 0	6·00	4·00
3	2·50	4·10	4·60	2·00	0·25	2·00	2 6	3 0	4 0	7·00	5·00
4	4·60	5·20	5·80	2·00	0·30	2·00	2 6	3 0	4 0	8·00	6·00
5	5·60	6·20	6·80	2·00	0·30	2·00	2 6	3 0	4 0	9·00	7·00
6	6·80	7·40	8·20	2·50	0·40	2·50	2 6	3 0	4 0	10·00	7·50
8	8·80	9·80	10·60	2·50	0·40	2·50	2 6	3 0	4 0	12·00	9·50
9	10·00	11·00	12·00	2·50	0·50	2·50	2 6	3 0	4 0	13·00	10·50
10	11·00	12·00	13·00	2·50	0·50	2·50	2 6	3 0	4 0	14·00	11·50
12	13·20	14·70	15·90	2·50	0·60	2·50	2 6	3 0	4 0	16·00	13·50
14	15·20	16·70	17·90	2·50	0·60	2·50	2 6	3 0	4 0	18·00	15·50
16	17·50	19·00	20·50	2·50	0·75	2·50	2 6	3 0	4 0	20·00	17·50
18	19·50	21·50	23·00	2·50	0·75	2·50	2 6	3 0	4 0	22·00	19·50
20	22·00	24·00	26·00	3·00	1·00	3·00	2 6	3 0	4 0	24·00	21·00
22	24·00	26·00	28·00	3·00	1·00	3·00	2 6	3 0	4 0	26·00	23·00
24	26·50	28·50	31·00	3·00	1·25	3·00	2 6	3 0	4 0	28·00	25·00

TABLE V. (*a* to *g*)—continued.

	45° Bends		135° Bends		90° Branches			45° Branches	
a	L	R	L	R	*h*	*l*	L	*l*	L
In.									
2	6·00	9·50	6·00	4·00	2·25	6·00	36·00	3·00	36·00
3	7·00	12·00	7·00	5·00	2·25	7·00	36·00	3·50	36·00
4	8·00	14·50	8·00	6·00	2·50	8·00	36·00	4·00	36·00
5	9·00	17·00	9·00	7·00	2·50	9·00	36·00	4·50	36·00
6	10·00	18·00	10·00	7·50	3·00	10·00	36·00	5·00	36·00
8	12·00	23·00	12·00	9·50	3·00	12·00	36·00	6·50	36·00
9	13·00	25·50	13·00	10·50	3·00	13·00	36·00	7·00	36·00
10	14·00	28·00	14·00	11·50	3·00	14·00	36·00	7·50	36·00
12	16·00	32·50	16·00	13·50	3·25	16·00	36·00	9·00	36·00
14	18·00	37·50	18·00	15·50	3·25	18·00	36·00	10·00	36·00
16	20·00	42·50	20·00	17·50	3·25	18·00	36·00	11·50	36·00
18	22·00	47·00	22·00	19·50	3·25	18·00	36·00	12·50	48·00
20	24·00	51·00	24·00	21·00	4·00	18·00	36·00	14·00	48·00
22	26·00	55·50	26·00	23·00	4·00	18·00	36·00		
24	28·00	60·00	28·00	25·00	4·25	18·00	36·00		

The erection of the socketed pipe is far too well known to deserve much comment here, and I beg to refer to the recent article in the *Chemical Trade Journal* on this subject. I think that we can now safely leave the subject of piping, both high and low pressure ones, and proceed to pressure vessels better known as acid eggs or monte-jus.

The strength of these vessels can be calculated in precisely the same manner as the pressure piping, and the same formula: $w = \frac{d \times p}{u \times 2}$ can be used. It will at once be clear that, whether the vessel is required to withstand internal or external pressure, the spherical form is the best and strongest, or a combination of cylindrical and spherical form. The factor which governs the capacity of such vessels is the wall thickness required to resist the pressure. You will readily understand that a vessel working under high pressure requires a very thick wall, so thick that it becomes very difficult to produce such a vessel from a practical point of view, as the wall will be difficult to dry and burn satisfactorily.

I have had some unfortunate experiences with very thick-walled vessels, and have found that $2\frac{1}{4}$ inches is about the limit which can with any degree of satisfaction be produced.

In order to get over some of the difficulties and to make a vessel of double the capacity, but of the same wall thickness as a spherical one, I would suggest that a cylindrical vessel with spherical ends is used, the formula applied in this case gives the same wall thickness all over.

As far as safety margin is concerned I should suggest that 2 is used, because a pressure vessel is generally protected

by being sunk into a pit, or, still better, surrounded by a strong wooden box filled entirely with sand, so that the vessel is not subjected to any outside influences which may endanger it.

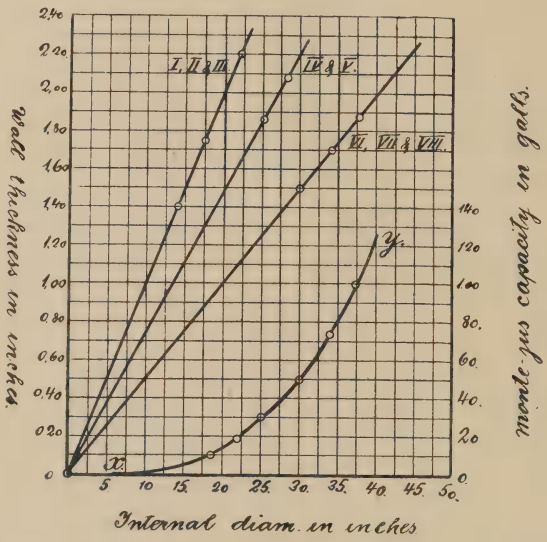


Fig. 6a.

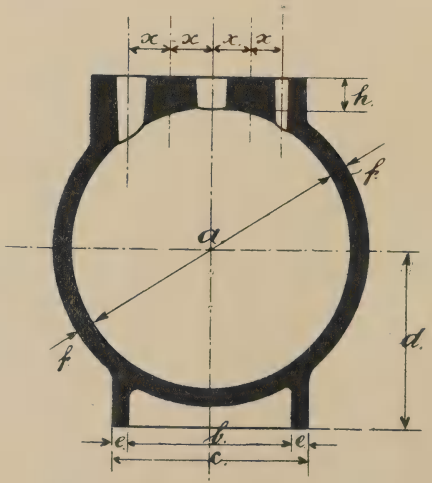


Fig. 6b.

TABLE VI. (*b*).

No.	Capacity	Working Pressure	*a*	*b*	*c*	*d*	*e*	*f*
I	5 galls.	60 lbs. sq. in.	13·75	8·25	10·75	12·00	1·25	1·50
II	10 ,,	60 ,, ,,	17·50	10·50	13·50	13·75	1·50	1·75
III	20 ,,	60 ,, ,,	22·00	13·25	16·50	16·00	1·75	2·20
IV	30 ,,	45 ,, ,,	25·00	15·00	18·00	17·50	1·50	1·90
V	40 ,,	45 ,, ,,	27·50	16·50	19·50	18·75	1·50	2·00
VI	50 ,,	30 ,, ,,	29·75	17·75	20·25	20·00	1·25	1·50
VII	75 ,,	30 ,, ,,	34·00	20·50	23·50	22·00	1·50	1·75
VIII	100 ,,	30 ,, ,,	37·50	23·50	26·50	23·75	1·50	2·00

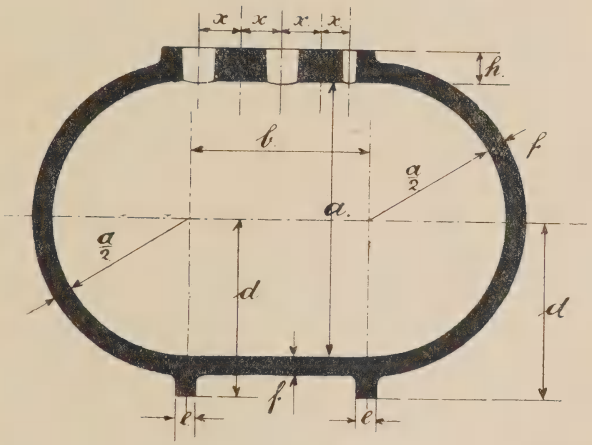


Fig. 6c.

TABLE VI. (*c*).

No.	Capacity	Working Pressure	*a*	*b*	*d*	*e*	*f*
I A.	10 galls.	60 lbs. sq. in.	13·75	9·25	12·00	1·25	1·50
II A.	20 ,,	60 ,, ,,	17·50	11·75	13·75	1·50	1·75
III A.	40 ,,	60 ,, ,,	22·00	14·50	16·0	1·75	2·20
IV A.	60 ,,	45 ,, ,,	25·00	16·75	17·50	1·50	1·90
V A.	80 ,,	45 ,, ,,	27·50	18·40	18·75	1·50	2·00
VI A.	100 ,,	30 ,, ,,	29·75	19·87	20·00	1·25	1·50
VII A.	150 ,,	30 ,, ,,	34·00	22·60	22·00	1·50	1·75
VIII A.	200 ,,	30 ,, ,,	37·50	25·00	23·75	1·50	2·00

I am giving a list of various sizes and dimensions, which should meet most cases, in Table VI, *b*, *c*, and I think that the diagram, Fig. 6a, might prove of interest. This diagram indicates the limit capacities for pressures and wall thicknesses, and curve *x—y*, gives the diameter for spherical vessels of certain volumes. Fig. 6b and Fig. 6c shows relatively the spherical and the combined form of double capacity.

You will notice that I have not provided any of the vessels with branches for inlet and outlet of the ordinary kind, as usually made, as I consider it a great mistake to stick on thin, comparatively weak necks to a great heavy vessel. You will agree with me that such necks always seem to break off on their own account; at any rate this is what the labourers who handle them always maintain, consequently a costly vessel is often rendered completely useless owing to this strange behaviour of the thin necks. I have found from experience that the only way to make a vessel fool-proof in this respect is to provide them with a thick heavy boss, which is relatively stronger than the vessel itself. This boss contains a conical hole into which an ordinary piece of standard pipe is ground, and the whole thing is fixed up at the place where the vessel is to be used, thereby minimizing breakages to a very great extent.

If the standard pipe should by any chance break off another piece is easily substituted, and the vessel is just as good as before. A simple method to keep the whole thing in position and at the same time joining up the next pipe is indicated in Fig. 6, *d—e*, and Table VI, *d—e*, which I think is clear enough without further explanations.

When a stoneware vessel is used as a pressure vessel it should be as dense and vitreous in body as possible, as otherwise during the time the liquid is subjected to the pressure it is liable to sweat; with liquids of low viscosity naturally the danger is greatest. A preventive treatment, which is quite successful in practice, is to fill the vessel before use with a strong sodium silicate solution, say one of silicate to four of warm water, and allow this mixture to remain therein, preferably under pressure for 24 hours; afterwards the vessel should be filled with acid, sulphuric or nitric, not too weak, for some few hours. The silicic acid is then separated out and fills the fine pores with a thick jelly substance, which is gradually hardened, and sweating is stopped.

I think that the pressure vessels have now received their due, and we might turn our attention to storage or stock jars, transport jars and Woulff's bottles (two and three neck bottles), as the immense variation in capacities and shapes of these is the cause of many troubles and delays in the erection of large

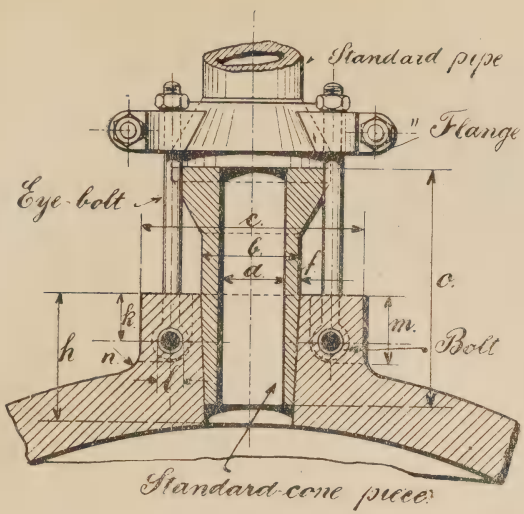


Fig. 6d.

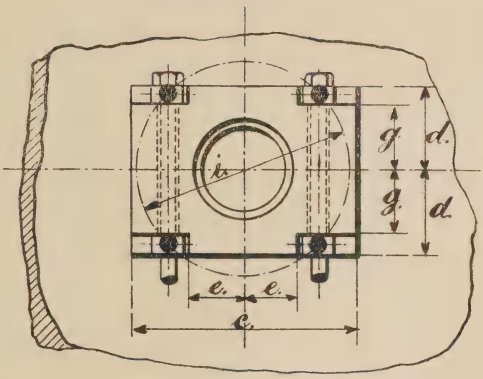


Fig. 6e.

TABLE VI. (*d* and *e*).

a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*k*	*l*	*m*	*n*	*o*
Ins.													
1	1·60	5·00	2·00	1·25	0·30	1·50	3·50	5·00	1·50	0·50	2·00	0·5	6·25
1½	2·30	5·80	2·25	1·50	0·40	1·75	4·00	5·80	1·50	0·62	2·125	0·5	6·87
2	3·00	6·60	2·75	1·75	0·50	2·00	4·25	6·60	1·50	0·62	2·25	0·5	7·50
2½	3·75	7·40	3·00	2·00	0·62	2·25	4·50	7·40	1·75	0·75	2·37	0·75	9·12
3	4·50	8·40	3·50	2·25	0·75	2·62	4·50	8·40	1·75	0·75	2·37	0·75	9·75
3½	5·25	9·40	4·00	2·50	0·87	3·00	5·00	9·40	2·00	0·87	2·75	0·75	11·25
4	6·00	10·40	4·50	2·75	1·00	3·40	5·00	10·40	2·00	0·87	2·75	0·75	11·75

chemical plants. We all know that these large-size parts require a long time for drying and manipulation, and they are very costly and difficult to replace if accidentally broken.

I think that the call for standardization is more urgent in this case than in any other, and I think that I have all chemical engineers behind me in this. I will give you a single instance how matters stood up to quite recently. A firm wanted a large number of one ton jars. They managed to secure them from one or two potteries. The jars arrived in due course, several of them were broken in transit, and semi-skilled labour unintentionally did their best to break a number of the rest, the result was, that, before the erection was finished, there was a very serious shortage of jars in spite of a certain number being allotted for spares. The people requested the makers to supply them with some more jars as quickly as possible; that could not be done, because meanwhile the makers were full up with other important Government work, and it was not much use going to other potters as these had to make the plaster moulds first, etc., etc., the jars of course not being their particular standard. Serious delay occurred—but who was to blame?

If a system of standards had been adopted throughout the country other makers would have had the moulds ready, they could have tackled the proposition at once, and no unreasonable delay would have been caused, and everybody would have been happy.

As the transport jars and storage jars are not subjected to any pressure, barring the pressure due to the weight of the liquid stored, which is not of much account, the guiding factor in determining the wall thickness must necessarily be one of practical experience, the vessels should be able to stand some rough usage without breaking, and the stronger they can be made the better, of course, within the practical drying and burning limit.

Table VIIA gives dimensions and thickness of large storage jars, which I have found to give satisfaction in everyday work, and it will in my opinion be very desirable to make the jars of sizes which correspond to convenient fractions of a ton.

You will notice from the Figure 7a belonging to the table that the bottom of the jar is slightly curved or domed inwards, and it will be clear that this form is far more able to withstand the weight of the liquid than a flat bottom, as the whole of the weight to be supported is carried outwards to the rim, and there is no possibility of the jar bearing on a bulge in the centre of the bottom and thereby endangering the safety of the vessel.

If any outlets are required they could conveniently be made of the same pattern as those mentioned under pressure jars, as it stands to reason that long, thin, easily broken necks should especially be avoided here.

Fig. 7b, and corresponding Table VIIb, give particulars of the top part and lid of a large storage vessel.

Cylindrical storage and stock jars are very convenient to have in the works, especially if they are of capacities of decimals of a ton ; stocktaking is greatly facilitated thereby.

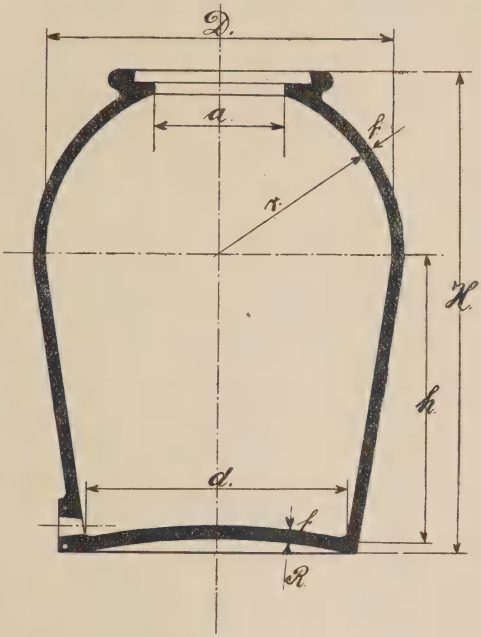


Fig. 7a.

TABLE VII. (*a*).

No.	Capacity	*a*	D	*d*	*f*	H	*h*	R	*r*	Weight of Water
	Galls.									Tons
I	55	12·00	27·25	20·50	1·25	38·625	22·50	55·00	13·625	0·25
II	110	12·00	34·25	25·75	1·25	47·875	28·50	70·00	17·125	0·50
III	165	16·00	39·00	29·25	1·50	54·70	32·20	80·00	19·50	0·75
IV	220	16·00	43·00	32·25	1·50	60·00	35·50	90·00	21·50	1·00
V	330	20·00	49·25	37·00	1·75	68·875	40·75	100·00	24·625	1·50
VI	440	20·00	52·25	39·25	2·00	73·325	43·20	110·00	26·125	2·00

The inside diameter of these jars should be the same as large bore standard pipes, so that the same presses could be used, although it might be necessary to have a slightly greater thickness of wall.

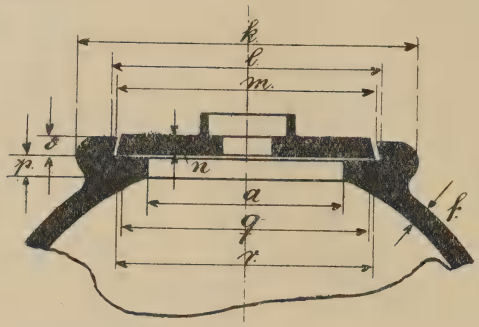


Fig. 7b.

TABLE VII. (*b*).

No.	*a*	*f*	*h*	*l*	*m*	*n*	*o*	*p*	*q*	*r*
I	12·00	1·25	22·00	17·00	16·25	1·25	1·25	1·25	15·25	16·00
II	12·00	1·25	22·00	17·00	16·25	1·25	1·25	1·25	15·25	16·00
III	16·00	1·50	28·00	22·00	21·25	1·50	1·50	1·50	20·25	21·00
IV	16·00	1·50	28·00	22·00	21·25	1·50	1·50	1·50	20·25	21·00
V	20·00	1·75	32·00	26·00	25·00	1·75	1·75	1·75	23·00	24·00
VI	20·00	2·00	32·00	26·00	25·00	2·00	2·00	2·00	23·00	24·00

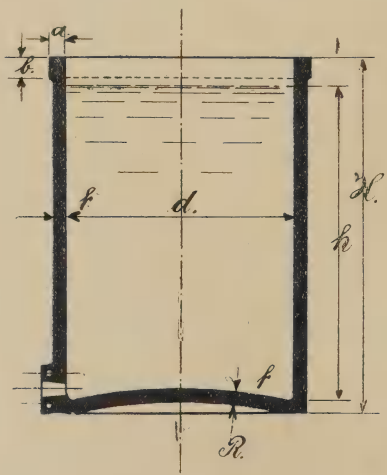


Fig. 7c.

TABLE VII. (*c*).

No	Capacity	Weight of Water	*a*	*b*	*d*	*f*	*h*	H	R
	Galls.	Tons							
I	11·1	0·05	1·50	2·00	14·00	1·25	20·00	22·00	44·00
II	22·2	0·10	1·50	2·00	18·00	1·25	24·00	26·00	52·00
III	44·4	0·20	1·50	2·00	22·00	1·25	32·00	34·00	68·00
IV	66·6	0·30	1·75	2·50	24·00	1·50	40·00	44·00	88·00
V	88·8	0·40	1·75	2·50	28·00	1·50	40·00	44·00	98·00
VI	110·0	0·50	1·75	2·50	30·00	1·50	40·00	44·00	108·00
VII	165·0	0·75	2·00	2·50	36·00	1·75	40·00	44·00	118·00
VIII	220·0	1·00	2·00	2·50	42·00	1·75	40·00	44·00	128·00

Fig. 7c gives particulars of a handy form which I should recommend to be carried out according to Table VIIc.

The necessity for proper standardizing of stoneware cooling, reaction or catch towers, is certainly as urgent as any of the other stoneware plant, and more so, as these towers are subjected to far more extensive working under varying temperature conditions, and therefore more liable to crack. Parts to be replaced should be easily obtainable everywhere, as the stopping for any length of time of such a tower will influence the output and the manufacture of the chemical works.

There is absolutely no necessity for having a great number of various diameters, the usual sizes, say 24 inch, 30 inch, 36 inch, 42 inch and 48 inch will produce a number of combinations quite sufficient to deal with any project which may crop up, as the height can be varied to suit the demands, and towers can be placed in series or parallel as required, so I feel quite confident in maintaining that the five sizes mentioned above are all that is required.

I do not think that it is necessary to go into the erection of the towers, as this is too well known and has been mentioned in a great number of text books and publications.

Fig. VIII, *a*, *b*, *c*, *d*, and Table VIII, *a*, *b*, *c*, *d*, give the forms and dimensions which Mr. Garrow and myself would suggest be adopted as standards.

Woulff's bottles or condensing receivers are not used to anything like the same extent, as some time ago; they are gradually giving way to more efficient apparata which lend themselves better to water-cooling. A good many are still used in the nitric acid and hydrochloric acid industry, especially on the Continent, and often where it is desirable to have large volumes of liquid in circulation throughout the plant in order to assure a steady and even absorption.

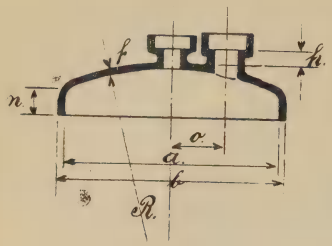


Fig 8a.

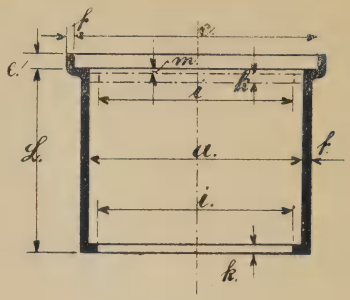


Fig. 8b.

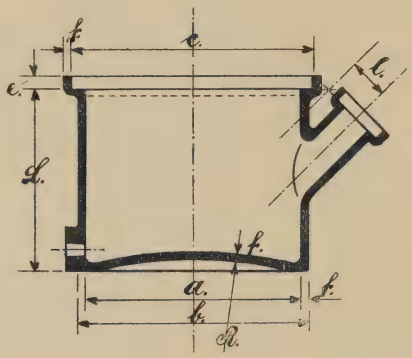


Fig. 8c.

TABLE VIII. (*a*—*b*—*c*).

Standard Dimensions								
a	*b*	*c*	*e*	*f*	L	L		R
24·00	26·50	28·50	3·00	1·25	30·00	36·00	According	88·00
30·00	32·50	34·50	3·00	1·25	30·00	36·00	to size	108·00
36·00	39·00	41·00	3·50	1·50	30·00	36·00	Branch,	118·00
42·00	45·00	47·50	3·50	1·50	30·00	36·00	see	128·00
48·00	51·50	54·00	3·50	1·75	30·00	36·00	Table V.	138·00

a	*i*	*k*	*m*	*h*	*n*	*o*	R	D	Plate
24·00	20·00	1·50	0·50	According	3·00	6·00	44·00	22·50	whole
30·00	26·00	1·50	0·50	to size	3·00	7·50	54·00	28·50	two halves
36·00	32·00	1·75	0·50	Branch,	3·50	9·00	59·00	34·50	two halves
42·00	38·00	1·75	0·75	see	3·50	10·50	64·00	40·00	3 parts
48·00	44·00	1·75	0·75	Table V.	3·50	12·00	69·00	44·00	3 parts

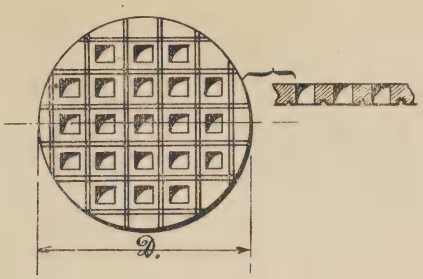


Fig. 8d.

TABLE VIII. (*d*).

Diameter of tower... ...	24 in.	30 in.	36 in.	42 in.
Plate thickness	1·5 in.	1·75 in.	2 in.	2·5 in.
Percentage of perforation...	50	50	50	44

In the nitric acid industry Woulff's bottles are generally used in connection with large bore vertical condensing pipes, serving as jointing boxes and collectors for condensate.

The predominant shapes are the pear-shaped, the cylindrical with flat bottom and the cylindrical bottles with conical bottom. In reality, it is more or less a matter of taste, which form is to be preferred, at any rate the top of the bottle should always be spherical, and the sockets for receiving the upright condensing pipes made according to standards.

There is still a great variety of miscellaneous stoneware plant which could be vastly improved by a proper standardizing system, but I am afraid that it would take up too much of your valuable time to go further into details. This should in my opinion rightly be done by a central committee of stoneware manufacturers, working in conjunction with some few experienced chemical engineers, as representing the chemical manufacturers' technical departments.

Some Suggested Improvements in Design of Chemical Stoneware Apparata on general Engineering Lines.

In the introduction I tried to point out the great mutual benefits which would accrue from the working together by the potter and the chemical engineer to a far greater extent than has hitherto been the case, especially as far as the designing of condensing and cooling plant is concerned. Take for instance an ordinary cooling coil, such as has been made and

used by the hundred; it is difficult to imagine a more ineffective form of cooling arrangement, or an apparatus giving more trouble and disappointment to the potter who makes it.

The coil is placed in a tub or cask, the speed of the cooling water is very slow, hence the heat units removed by the cooling water are few. By a properly designed coil and container it is possible to double or treble the work of the coil per unit of surface. The formula for the surface-heat-transfer-coefficient between a stoneware coil and the surrounding water is $k = a\sqrt{b}$, where k = heat units conducted away per unit of surface per hour per degree mean temperature difference, a = a coefficient according to the density or metalline consistency of the stoneware; for quite smooth surfaces a higher value can be taken than for rough or unglazed surfaces; b = speed of the cooling water past the surfaces.

This formula shows clearly that if the speed of the cooling water, for instance, is increased four times, the value of k is doubled, if the speed is increased nine times k becomes three times as big. Now with ordinary circular coils this cannot be done without using an undue amount of cooling water. If the coil, however, was flattened out, similar to a grid, it would occupy a much smaller space, and hence the speed of the cooling water would be greater, besides the cost of producing such a flat coil for the same cooling area is somewhere about half that of a circular coil. Stresses due to expansion and contraction are practically eliminated, and therefore the life of the coil would be much longer.

Then take corrosive fumes or gas coolers, made up from large bore pipes, say 4 inches or more. The cooling action of the wall only penetrates 1 inch to 1½ inch into the interior of the pipes; an untouched hot core is formed in the centre part of the pipes, and this core naturally greatly reduces the cooling efficiency.

The gas current should be split up and caused to whirl by means of spirals inserted in the pipes. I have found in practice that the cooling effect is improved 20 to 30 per cent. by this arrangement.

Direct cooling by means of an inert liquid, which in turn is cooled by an improved coil, is by far the most efficient method of dealing with large volumes of corrosive fumes, as it is possible to obtain a many times greater cooling surface in a tower by means of modern tower-filling, well wetted, than by using a large number of large bore stoneware pipes. If no suitable inert liquid can be found the fume current should be divided up into a number of smaller streams, such as is done for instance

in the Hart condenser. This is a very efficient apparatus as far as it goes, but it can also be greatly improved upon.

It is particularly in the cooling and condensing problems that the chemical engineer, who has made a speciality of the behaviour and the physical properties of fumes and liquids under various conditions, can be of greatest assistance and use to the stoneware manufacturers. I have not the slightest doubt but that such engineers can be found, and it is only by improved designs of guaranteed efficiency that stoneware can compete against rival materials.

The question of pumping and dealing with corrosive liquids and fumes presents many pretty problems, which in my opinion can only be successfully solved by the stoneware manufacturer in conjunction with the chemical engineer. It is first and foremost a matter of efficiency ; why should the chemical manufacturer be content with a much lower efficiency when he is pumping acid than when he is pumping clean water? Low efficiency means waste of power, which again means increased demands upon the coalfields.

There is no reason why automatic monte-jus should not be substituted for the old-fashioned hand-worked ones, and well designed plunger pumps or centrifugal pumps be far more extensively used, once good, efficient and practical types are evolved. Pumps, of course, should always be subjected to careful tests before leaving the works, and their output guaranteed. It is unfortunately only too often that when a chemical manufacturer asks for particulars as to guarantees, etc., he gets the reply : We do not give any ; we think, however, that the pump will do the work. These vague statements are not very reassuring to the chemical manufacturer, and no one can blame him for selecting a metal alloy pump, as he thinks he is on safer ground. A good design will give the stoneware manufacturer confidence in his plant, and this confidence will in turn be imparted to the user.

The storing in bulk of large quantities of corrosive liquids is also a problem of first magnitude ; even the largest practically made storage jars, containing two tons, are not always sufficient, and built-up tanks must be resorted to ; here the stoneware manufacturer can be of great assistance to the chemical manufacturer.

There is a great demand for properly designed picric acid pots and nitrating vessels, things which will stand change in temperature without cracking, and here the design is as important as the material itself.

"All stoneware" hydro extractors would be extremely useful for dealing with nitratings and chlorinatings. They are

used to a great extent on the Continent, where purity and consequently safety is demanded. I may be mistaken, but I have not yet seen a stoneware hydro made by an English stoneware manufacturer.

There is no mystery about the thing, it is only a question of intelligent designing and co-operation between the chemical engineer and the stoneware manufacturer, working along on well-known engineering lines.

Gentlemen, I could mention many more pieces of chemical plant to-day waiting remodelling by the specially trained designer's hand, but time is an object, and, I will only say in conclusion, that if the chemical stoneware market in the United Kingdom, Overseas Dominions, and last, but not least, the Allied and certain neutral countries, after this war and subsequent reconstruction, is to be kept for the English stoneware manufacturers, namely you, gentlemen, I think that it is high time that something was done along the suggested lines, or better lines, laid down by more capable men than myself, and without waiting for any Government department to give a lead.

Some few Suggestions regarding Improvements in Plant and Machinery for turning out a high class Product.

As the best tool makes the best product, it is clear, that in order to manufacture the best and most modern stoneware plant, the works must be equipped with the proper plant and facilities for doing so.

First of all, there is the raw material, it must be selected with care, and be under expert supervision from start to finish. If something goes wrong the cause should be ascertained at once, whether it is due to faulty preparation or blending. Efficient grinding and sifting plant is of great importance, extreme fineness of the plastic clay and unity of the various sizes of grog found most suitable for the purpose in view should be insisted upon. In this connection the close fine texture of Continental stoneware should be noted.

Blending must never be done by rule of thumb; uniform strength can only be secured by uniform raw material.

Then there is the "weathering" of the clay mixture; not weeks, nay many months and years should be the time allowed for the clay to get into the proper colloidal state so necessary for success. I do not know, but I am told, that this does not quite receive the attention it deserves in this country as far as some works are concerned. Of course it means a comparatively large ground space set aside for this particular purpose, but it

will be found that it will pay handsomely in the long run. On the Continent I have found that a large weathering store was always provided for in a high class chemical stoneware works. If ground space and capital permits it, the store should be a large shed, constructed in such a manner that the material stored is not exposed to any violent temperature changes, for instance a night's sudden frost, and so on. The store should be divided up in compartments or bins, where each large consignment of raw material is kept apart and date of arrival in storehouse recorded.

Machinery should replace hand labour to as great an extent as possible, so that a quick turnout of a uniform article at low cost is assured. I have seen abroad a storage jar of 1½ tons capacity being turned out, complete in plaster-of-Paris moulds, in 20 minutes, simply by employing suitable machinery. It was done in this way: A huge, slowly revolving potter's wheel, about six feet diameter, was partly sunk into the floor, a plaster-of-Paris mould in three or four parts corresponding to the outside of the lower half of the storage jar was firmly fixed to a strong iron platform on four small trolley wheels. The whole arrangement was wheeled on to the "potter's wheel," a simple but quick method for centreing and keeping the platform in position being arranged for. A huge, scraper-like instrument of a form corresponding to the inner shape of the jar was forced into the now rotating mould, at a distance from this according to the wall thickness desired; two operators, standing one on each side of the machine, threw lumps of clay as fast as they could into the mould. The lumps were quickly smoothed and kneaded into the exact form by the scraper, and the lower half of the jar was ready. The top part was made in precisely the same way. The parts were wheeled off from the potters wheel to the drying departments, and I noticed that the parts were numbered, so that, as far as possible, a bottom and a top part made within the same day or two were always joined together after drying. The jars also remained on the small carrier until drying was complete, so that the transport was very easy. As the result of this quick work, and the easy handling, a jar of this size could be put on the market and sold in this country for £8 to £10, which, I may say, is very considerably cheaper than any jars of similar size I have obtained quotations for in this country.

Screw presses are very convenient for pipes of smaller diameter, say up to 8 inches, and, according to my view, the die should be arranged horizontally, so that the pipe is shot vertically upwards between guides. I think that in this way a number of fine surface cracks can be avoided, which are

otherwise very liable to be formed when the pipes are shot out horizontally on a table.

Large bore pipes and tower sections should be pressed out from vertical hydraulic presses situated on a floor above an intermediate working floor, so that plenty of space is allowed underneath for the weight-balanced receiving table situated under the press.

Stop-cock bodies and plugs should be pressed out in one operation on machines similar to brick and tile presses, and under as great a pressure as possible in order to secure an article free from the irritating minute cavities so often found in parts not pressed. Pressing and pressing seems to me to be the thing abroad; every multiple article, which can in any way be pressed, should be pressed. Of course dies are not cheap, but, once made, they are there, and I think that it would probably pay well to evolve a few standard presses, taking a great number of "standard" outside dimensioned dies, so as to reduce the first cost of the plant as much as possible.

The proper drying of the moulded or pressed parts should receive the greatest attention, and much more than it actually does in many cases. The large amount of waste heat from the kilns should be used either directly or passed through heating ducts made from sheet iron, or, if more convenient, a hot water pipe system can be arranged, so that the drying is under more complete control than if air drying, depending upon the outside atmospheric conditions, is to be relied on. The most convenient place for the drying chamber is naturally on top of the kiln. In this way two birds are killed with one stone, a saving in fuel is effected because the kiln is enclosed in a building, and the heat otherwise lost by radiation to the outside air is made use of for the drying; and further, when a compartment of the kiln is opened out, the fired stoneware is not so liable to be chilled.

In my opinion a modern continuous tunnel kiln on the Dressler lines seems to be the thing for the lighter articles, and a producer gas-fired down-draught multiple chamber kiln for the heavier pieces. A part of the waste heat not required for drying purposes should be passed to a regenerator arrangement in order to preheat the air necessary for the combustion of the producer gas.

The importance of careful grinding cannot in my opinion be sufficiently emphasised, and it is here, in this department, that there is great room for improvements. All flanged joints should be absolutely straight and true ground if a lasting tight joint is to be made; stop-cocks, their bodies and plugs, should be separately ground to a standard taper, and only the final

grinding or polishing, so to speak, should be done by grinding the plug into the body. It is a mistake to believe that costly and intricate machinery is required to produce good results. The pulley parts of a couple of old lathes will work wonders as grinding machines, and there is no end to the number of cheap and efficient grinding machines which an intelligent mechanic can produce from old lathes and drilling machines. I have seen it done. I think that there will shortly be a great chance to procure precisely what is wanted in this direction when the shell-turning lathes are devoted to a more peaceful work, or, shall we say, continue the defensive trade war afterwards.

I have said before that no stoneware piece should be allowed to leave the works unless after most careful examinations and tests to ascertain that the article really fulfils all the requirements.

In this way the potter himself discovers possible faults in material and construction, and does not get his reputation damaged by leaving the discovery of the faults to the buyer. Well, I think that the importance of this is clear enough and requires no further comments.

It stands to reason that the more scientific and perfect the complete control is, both chemically and physically, of the manufacture in the various stages, from selecting and testing the raw material, grinding of same, moulding, pressing, drying, firing, finishing, testing, etc., etc., the better it is, and the better it pays in the long run.

Every pottery should of course have one or more chemists, but naturally nobody expects every potter to have a complete, highly trained scientific staff with elaborate chemical and physical laboratories. I do not see any reasons why all pottery products should not be controlled or supervised by an independent, consulting central bureau, employing the best brains, having opportunities of following up the latest developments taking place at home and abroad, and carefully extracting, sifting and indexing real useful data obtained. Such a bureau should be partly supported by the potters, but to the greatest extent by the State, if the State can be induced to move in the matter. A complete testing plant should be arranged in conjunction with this bureau, and a report from this should be final and binding for all parties.

Amongst the duties of this bureau should be the calculations and designs of efficient new standards for all prevailing purposes, on proper scientific and therefore correct lines, and its services should be *free* to all manufacturers and users of chemical stoneware.

To my mind, once this bureau of, shall we call it *Bureau of Standards* is started, it would be a great step onwards to the ideal conditions we all look forward to, stoneware manufacturers and chemical manufacturers, and certainly chemical engineers alike.

DISCUSSION.

Mr. B. J. ALLEN:—I have the very greatest pleasure in proposing a hearty vote of thanks to Mr. Nielsen for a paper which, in scope and value, is, I think, invaluable. Unfortunately, to-night is unsuitable for many of the stoneware manufacturers to be here, and possibly we may not get the discussion that the paper merits.

It is very evident that some sort of standardization has got to take place. It is surprising, when one comes into contact with the stoneware manufacturers in this country, to find how crude are some of the ideas that they work upon. In some cases, I believe, the thicknesses of the pipes they produce depend entirely upon the size of the die with which the engineer thinks fit to supply them. The pipes are made with no idea at all of producing anything of a definite strength; they just come out of the pipe machine that particular size, and are considered to be "good enough." In some branches of the stoneware trade—I am referring now not to stoneware used specially for chemical purposes—standardization might also be brought about with very great advantage. The only obstacle I can see in the way of standardization being generally adopted is the fear some manufacturers have of losing their individuality. One comes across firms who think that they have certain specialities that no one else has got, and they do not feel inclined to co-operate towards standardization for fear of giving something away. And the strange thing is that often those firms who are most afraid of giving away their secrets have the least to give away. If only Mr. Nielsen's remarks can be brought before the notice of these individuals, and some sort of start made in the way of standardizing productions, then I think the success of the British stoneware industry will be assured.

The Germans, I feel sure, have no better raw materials than we have, in fact, probably nothing so good, otherwise they would not go to the trouble of importing raw materials from this country. But it is significant that they *manufacture* their stoneware; they are not content to take the raw materials straight from the earth, and turn them into stoneware pipes and so on, trusting to luck for them to come out satisfactorily;

and that, I am afraid, has been the case with many of our own stoneware potters.

In Mr. Nielsen's paper we have the basis of an engineer's standard for chemical stoneware, and we have a Pottery School that is quite equal to dealing with the ceramic side, so that it ought not to be difficult for the potter and the engineer to co-operate, and to produce articles which will successfully compete with the German manufacturer, not only in price but in quality.

The introduction of further mechanical means of manufacturing stoneware articles seems to me to be absolutely essential, for the more you can eliminate the human element, and avoid building up articles of this kind in small pieces, the better it will be for the pottery. I feel sure that Mr. Nielsen's remarks will commend themselves in many respects to stoneware manufacturers, and that great benefits will accrue.

There is only one point in Mr. Nielsen's paper that I do not quite like from a potter's point of view, and that is in connection with the illustration 6b, which he put on the screen, showing a method of holding down the eye-bolts. To my mind that circular ring running round the neck of the jar seems a very difficult thing for a potter to make satisfactorily, and apart from this, it seems better that such parts as these should be left exposed. I imagine that the outer ring holding the eye-bolts is a very difficult thing to produce satisfactorily, and it seems to me that something in the nature of a bayonet joint to hold the ring would be a better mechanical arrangement and easier to produce.

In conclusion, I would like to say that I read the papers of Mr. Nielsen and his friend Mr. Garrow published in the *Chemical Trade Journal*, and I felt at the time that they were the most useful papers that had ever been written in connection with the stoneware industry. From my own point of view I have found them of great value, and I have the greatest pleasure in proposing now that the heartiest thanks of this Society be given to Mr. Nielsen for his very valuable paper.

Mr. A. LEESE:—I have much pleasure in seconding the vote of thanks to Mr. Nielsen for his interesting paper. By the thoroughly practical way in which he has illustrated and explained in every detail the erection and use of chemical stoneware employed in the manufacture of highly corrosive acids, he has shown himself to be a real master of his work.

I am afraid that this important branch of pottery manufacture is somewhat foreign to most of us here in the Staffordshire Potteries; at the same time the paper illustrates very

clearly how important it is that certain definite standards should be set up and rigidly adhered to for shapes, fittings, sizes, density of body, tensile strength, etc.

No doubt this is going to be a troublesome and expensive matter to some of the manufacturers to get started, but if such a standard could be established manufacturers and all concerned would very soon find it to their benefit, and a give and take principle would spring up between suppliers and users, with a desire to help one another out of difficulties, and to arrive at a more successful production. Very often failure rests upon the omission of some small detail which one does not grasp straight away, but which can soon be put right by mutual intercourse, and a sense of freedom in the expression of opinions with regard to such difficulties from time to time. I am sure we all trust that Mr. Nielsen's efforts in this direction may eventually result in the standards he is aiming at.

Mr. M. BARRETT :—I welcome this admirable paper, and would say at once that I am in entire agreement with the author in the endeavour which he is making to effect the standardization of stoneware vessels used in the chemical industry.

All manufacturers of chemical stoneware would, I think, be willing parties to any scheme which would result in the simplification and standardization of patterns as much unnecessary trouble has result in the past from the multiplicity and the incorrect design of vessels, etc.

Although it is undoubtedly true that the German manufacturers have gone much further than we have in the matter of standardization, the author, I think, flatters them unduly. In the *Zeits. angew. Chem.*, September 20th, 1918, is a reference to a meeting of the Verein deutscher Chemiker, at which was discussed the question of forming a Subject Group of the Society for promoting the simplification and standardization of chemical apparatus and plant in general.

It is my experience that the design of a large vessel is much more important than the particular clay mixture which is used, and in designing pottery on engineering lines great caution should be exercised and the natural limitations of the material kept prominently to the fore.

The care used in filling the moulds is secondary only in importance to the design, and in my opinion infinitely more important than the mixture used. Strains which are set up in drying, burning, and in use, have their origin primarily in the incorrect design or careless filling of the moulds. In this connection I might mention that large vessels with small

rounded bottoms are infinitely to be preferred to those with large flat bases.

It is rather a common experience to be told that chemical stoneware to be of first grade quality must be thoroughly vitrified, *i.e.*, non-porous, and specifications not infrequently call for a water absorption under 1 per cent. I was interested some years ago in determining the absorption of two representative pieces of high grade German chemical stoneware, and the figures obtained were at that time considered to be surprising :—

German stoneware, A, absorption = 3·54 per cent.
„ B, „ = 4·94 „

One would expect that vessels showing this porosity would leak, or at least sweat when used, for instance, with liquids of low viscosity, particularly when under pressure, but this does not occur, and the explanation is, I think, to be found in the exceedingly small size of the pores. The mixtures used in Germany for large as well as small vessels is exceedingly fine-grained, and in this respect differs materially from most of the English mixtures which for the most part contain a proportion of grog of appreciable size. Such a body showing an absorption approaching 5 per cent. would most certainly sweat and be unsatisfactory.

One important advantage of standardization is the encouragement which is given to the use of the casting process. Cast pots are likely to be freer from strains and much more even in thickness, and this cannot help but have a favourable influence on the life of the pot in use.

Chemical stoneware should be quite impervious to corrosive liquids and gases without the superficial protection of a glaze, and the sole function of the latter should be to enable the vessels to be more easily cleaned. The suitability of the salt glaze for the purpose has been much over-rated, and the popular opinion that this type of glaze is the "ideal" is, I suggest, untrue. Such glazes are frequently too alkaline and are almost invariably covered with a fine network of crazes. It has been my experience that infinitely better results are obtained by using a felspathic glaze of the porcelain type, the composition of which is under control and which can be modified to suit varying conditions.

Probably the most effective way of furthering this work of standardization would be to appoint a small committee consisting of, say, three chemical engineers, three prominent users and three manufacturers. All three interests have now their own organizations, namely, The Chemical Engineering

Group of the Society of Chemical Industry, The British Chemical Manufacturers' Association, and this Society, and I beg to move that such a committee be appointed.

Mr. W. HAYHURST :—I will only refer to three matters in the paper : the questions of thermal conductivity of stoneware, pumping, and the manufacture of stoneware taps.

In regard to the thermal conductivity of stoneware I think we were among the first to draw attention to the importance of this subject, and in fact devoted so much research to it that we prepared ceramic compositions particularly designed for relatively high thermal conductivity.

According to reports to hand, liquids may be boiled and evaporated in basins of our ceramic material designed for thermal conductivity as rapidly as in basins of ferro-silicon alloys.

In my own chemical engineering practice I have found it desirable, especially when cooling large quantities of gas, to prepare materials of varying thermal conductivity, and as a matter of convenience we keep about four or five grades of bodies for this purpose.

The question of pump design and adoption of ceramic materials, therefore, is a very important one. I am not in agreement with the writer when he states that the first question is efficiency. The efficiency of centrifugal pumps, for example, is so much greater than the efficiency of compressed air systems, which are principally alternative, that one can well afford to purchase greater reliability and strength at the expense of some efficiency and yet be much more highly efficient than the compressed air system.

In my opinion satisfactory centrifugal pumps in ceramic material cannot be designed on general engineering lines if they are to be highly satisfactory, and I have found it necessary in my own design work to depart from normal designs in important particulars. These designs have been carefully checked by experiments and refer especially to impellers.

It may interest the members of your Society to know that we have ceramic pumps capable of handling boiling acids lifting to 100 ft. at low revolutions.

I am pleased to note that the writer continues to emphasize the importance of grinding in the manufacture of taps. Very few English taps are accurately ground, and my experience has been that the most economical tap is the one which is ground most carefully, even though this brings up the first cost.

Prof. J. W. HINCHLEY:—This contribution to the standardization of chemical plant is a most valuable one, and I wish to offer Mr. Nielsen the heartiest encouragement.

In a material like stoneware the assumption that strength is proportion to thickness is unsound, of course, but it is not easy, unless one is dealing with a particular brand as a manufacturer, to offer any alternative. I am of opinion that the only element of standardization which should be insisted on is that replacements can be made from any manufacturer's output. With such a basis a *standard thickness* would not be essential and would avoid the risk of preventing improvement of the material itself.

The strength of stoneware varies far more than is usually supposed, and the thickest parts are often the weakest. The process and care exercised in manufacture have too much influence to enable one to settle standard designs without the co-operation of the manufacturer, and the remarks of Mr. Nielsen on manufacturing are much to the point.

In the manufacture of parts by pressing, I do not think that "as great a pressure as possible" is likely to remove the air from cavities, and to secure what Mr. Nielsen desires. In fact it is easy to weaken the material considerably by this plan.

Finally, there is little doubt that the strength and limit of thickness of stoneware may be considerably increased by development on bold scientific lines, and it is most important that standardization should not prevent the introduction of new and better material than that we are now familiar with.

Mr. D. F. W. BISHOP:—I must plead guilty to not having really read through this paper before I came into the room, and I am sorry to have to say so, because, although some of us may not be directly interested—and I personally am not—in the manufacture of these classes of articles, yet it does cause one seriously to think, and I am looking forward very much to examining the specimens that Mr. Nielsen has brought with him at the end of the meeting.

There is one statement in Mr. Nielsen's paper which I would like to ask a word about, because it seems contrary to our experience of clays in this district. I refer to his remarks about weathering, in regard to which he says: "If ground space and capital permits it, the store should be a large shed, constructed in such a manner that the material stored is not exposed to any violent temperature changes, for instance, a night's sudden frost and so on." Is that really correct, because, rightly or wrongly, I believe most of us in this district think

that the more our clays can be broken up by weather changes and weather effects the better it will be for the working of the clay and for its durability in the finished goods?

Mr. NIELSEN:—I am sorry I am not a potter, and I understand nothing at all about the chemical part of potting; but from what I have been told defective pottery is often attributed to bad weathering, and certainly very often defects have been explained by manufacturers to be due to unfavourable weather conditions and that sort of thing at the time the ware was made.

Mr. BISHOP:—Evidently they were referring to the working of clay in the finished state.

Mr. A. HEATH:—That is how I took it. The suggested storing sheds are for clay in its finished state.

Mr. NIELSEN:—I was probably wrong in saying the "raw material." I should have said the mixed clay.

Mr. HEATH:—I think we should understand that better by the term "ageing."

Mr. B. J. ALLEN:—In one of the communicated discussions a mention is made about the standardization of material. I think that is quite as desirable as the standardization of shapes, thicknesses and the rest. I do not know that there is any real specification for a "stoneware pipe." It may be anything that is tubular. It may be vitreous, or it may not; it may depend for its durability upon a mere slip coating. This is one of the ways in which our Pottery School can score—standardize and specify the clay materials—to tell us how to prepare the material to compete with anything that may be turned out by German or any other competitor.

Mr. NIELSEN:—I understand stoneware to be vitreous material, not soft ware—a material where you do not rely at all upon the glaze or a covering of slip. It is not sufficient that a piece of stoneware shall be acid proof for a few minutes, it needs to stand the test for months and months.

Mr. W. EMERY:—I should like to ask Mr. Nielsen a question with regard to the screw presses for the manufacture of pipes. He mentions the fact that surface cracks can be avoided by arranging the dies vertically instead of horizontally. I should be glad to hear how he explains that.

Mr. NIELSEN:—I have found that in many cases where you use a horizontal die, in actual practice the table is often a quarter of an inch or so out of alignment with the die, and a strain is set up. If the pipes are pressed comparatively dry the mere fact of this small variation is of itself quite sufficient to promote cracks. If, on the other hand, the pipes are pressed vertically, the weight of the pipe, which may be considerable in a large pipe, tends to keep the material closer together. I do not know that I can explain the matter in a satisfactory technical way, but certainly the German manufacturers had most of their pipes for the manufacture of coils shot up vertically, with suitable guides fixed to prevent wobbling, and they contended that this system had the effect of avoiding cracking.

Mr. EMERY:—Do the cracks only appear on the under side of the pipe when pressed by the horizontal die?

Mr. NIELSEN:—I could not be certain, but I think they do. Secondly, I understand that a certain amount of friction takes place between the clay and the table, whereas, if you shoot the pipes up vertically, you avoid the friction almost entirely, and you get rid of a lot of strains that way.

Mr. A. LEESE:—Whilst on this question of vertical dies I might mention that the perpendicular pugs used to be condemned on general pottery works, for the reason that it was thought that the weight of the clay did not add to the quality of the clay when pugged. In a vertical system there is a certain amount of resistance to the pressure required to cut the clay up, and force it through the machine. It takes greater pressure to force the clay upwards, and this must have the effect of bringing the particles closer together.

Mr. NIELSEN:—But you have to bear in mind that the pressure inside the press is simply terrific, so that a slight back-pressure due to the mere weight of the material would not, I think, play a very great part in changing the qualities of the clay. Besides, for high-class chemical stoneware the material used is in a comparatively dry state in order to give that necessary high pressure. If the material was too wet it would simply squirt out of the die. The pressure is, I think, anything between 25 and 30 atmospheres, equal to about 420 lbs. per square inch—sometimes more. Very powerful hydraulic presses are used for the purpose.

Mr. LEWIS JOHNSON:—I should like to say that although, in a way, I am not at all interested in the manufacture of stoneware of the types mentioned in the paper, Mr. Nielsen's contribution certainly teaches us quite another art of pottery. For my own part I had no idea that some of these types of thing are being made in pottery at all, and although many of Mr. Nielsen's suggestions will not apply directly to the potters of North Staffordshire, he has certainly given us some ideas in relation to other things, particularly in the sanitary departments. I am sure we are all very much indebted to Mr. Nielsen for his paper.

Mr. G. A. HODSON (Loughborough):—I am in entire agreement with the general suggestions of the lecturer as regards the principles of the standardization of chemical stoneware.

The question, it seems to me, that concerns the manufacturers of this country is, would they be justified in going to the expense of organising their works and the trade on such ideal lines. Would the demand be such as to warrant the outlay. The skilled staff necessary to carry out the details suggested by the author would be very costly, and the output would have to be a large one to show any return on the capital expenditure.

We must remember the conditions that prevailed when the Germans captured the stoneware trade do not exist to-day. They had practically no serious competitors, and therefore had a period of years in which to perfect their organizations and products. The conditions that exist to-day are very different, we have not only a formidable competitor in the great perfectly organised German factories, but the demand for war purposes has induced clay firms all over the country and America, also France, to enter the field of competition, and those firms who were makers of chemical ware previous to the war have greatly increased their capacity.

Taking all this into consideration, is it going to be worth while to incur the expense necessary to carry out all the suggestions of the author of the paper.

In coming to a decision we must bear in mind the fact that, owing to existing competition, the transformation would have to be brought about quickly, and could not, in the German case, be spread over a period of time.

I certainly think that some simple form of standardization of pipes, storage vessels, etc., could be adopted with advantage to both makers and users.

With regard to fixing a standard thickness of metal for the various pieces, I do not think this would be possible in a general sense, as what would be a safe working standard for one particular stoneware would be hopelessly out of it for another.

Mr. C. E. RAMSDEN:—I would like to say that I have seen a good many stoneware pipes made in Devonshire, and they were all made vertically. I was very much interested in the remarks about the suitability of our materials, because we sent many hundred of thousands of tons of our best stoneware clays to Germany. There is no question that we possess the material, and I think from what I have heard here to-night we have also the brains. Two practical suggestions have been made—one in Mr. Nielsen's paper as to a Bureau of Standards, and the other from Mr. Barrett, of Leeds, that a committee be appointed consisting of manufacturers, users and engineers. I think the idea an excellent one, and if anything came of the deliberations of such a committee, some Central Bureau, whose opinions and tests would be acceptable to all parties, would be necessary. In that event no better place could be found for that Bureau than the Pottery School at Stoke-on-Trent. The Stoke Laboratory and The Ceramic Society would form an excellent tribunal, and perhaps Dr. Mellor will give this matter his consideration.

Mr. NIELSEN:—Mr. Allen's kind criticism has pleased me much, and I think that Mr. Allen is quite right in his remarks regarding the manufacture of chemical stoneware at some works in this country. I believe, however, that he has misread the figure he mentioned, as there is no circular ring round the neck of the jar. The holding-down bolts are secured by straight through bolts, resting in straight through holes in the boss, as shown in plan view, Fig. 6e.

Mr. Leese's remarks about the first costs of the introduction of the standards are much to the point. A certain outlay is necessary, but this outlay should certainly be judged by the positive return as far as convenience, labour-saving and reduced production costs in the long run are concerned.

A very similar case is machine moulding in an iron foundry. The moulding machine is expensive, but once there it saves its first cost over and over again in a short space of time. Another point to be remembered is that the change over to standard sizes will naturally be a gradual one, and one die will suit several purposes, and, being a general standard pattern, will cost relatively little.

I do not quite agree with Mr. Barrett when he says that I flatter the Germans unduly, this was certainly not my intention. I think, however, that the sooner we admit their ability in certain directions the sooner we shall be in a position to beat them at their own game.

The figures Mr. Barrett gives regarding the absorption of German stoneware certainly astonish me, and I still wonder if there is not a clerical error in the place of the decimals, so that it should read ·39 and ·49 respectively.

Mr. Barrett's suggestion towards the formation of a small committee for dealing with standardization properly is a very good one, and I sincerely hope that such a committee will be formed in the near future.

I must admit that I do not see the points in Mr. Hayhurst's comments, and I do not think that they have any direct bearing on the subject to hand, barring stating the excellence of his special material, on which I congratulate him.

I do not agree with Mr. Hayhurst's views regarding the great benefits obtained by using material of varying thermal conductivity. According to my personal experience in the chemical industry, the higher the thermal conductivity the better it is, whether for cooling or heating purposes, and I fancy that most engineers will agree with me.

I am sorry that Mr. Hayhurst has taken my remarks "on engineering lines" literally. I beg leave to withdraw this and substitute, "on engineering lines with due regards to the material."

With reference to Prof. Hinchley's remarks; personally, I am not satisfied that the strength is proportional to the thickness in all cases, and I am still bewailing that more research work has not been done in this and other countries to clear this matter up from a scientific point of view.

From certain practical experience I think that I am justified in my assumption, within the limits of thicknesses employed in my suggested standards, and I think that uniform thickness of pipe walls of same bore pipes is rather important, and I did draw attention to this under the heading of suggested standards, where I make a rough classifying of pipes in good and better ones, giving everybody who makes good stoneware a chance.

Instead of retarding improvements in the material itself, I rather think that the manufacturers will be spurred on thereby, so that their pipes can come in a higher class.

I agree with Prof. Hinchley that the thickest parts are often the weakest, but this is probably due to faults in the present way of manufacture, and I am optimistic enough to

hope that the future research work will throw more light on this subject.

I think that Dr. Mellor's excellent idea of annealing, which he mentioned to me a short time ago, will be of greatest value towards getting rid of the contrary stresses in the material itself, which are weakening the finished article.

I also venture to hope that the standardization of chemical stoneware will not prevent the introduction of better material, on the contrary, why should the stoneware industry be an isolated case in this respect?

I am rather sorry that Mr. Hodson takes such a pessimistic view of the chemical stoneware industry in this country, and voices the typical British pre-war sentiments.

It certainly always pays to cut down manufacturing costs and to have competent scientific supervision in any class of manufacture (stoneware as well). This is being done in all industries every day, with the object in view of meeting competition, and further, I am going to put a straight question to Mr. Hodson: Why and how did the Germans capture the stoneware trade (and other trades), and I will ask him to consider his reply well?

Now Mr. Hodson says: "Is it worth while?" and, reading between the lines, what is the good of bothering, people from the States, France and Germany will come along again. This is just precisely what the British stoneware manufacturers are up against, and in order to assist them to the best of our ability Mr. Garrow and I started the standardization movement.

Mr. Hodson need not have any fears, there is plenty of work to go all round; nearly all the chemical plants in this country have been worked to death, and parts must be replaced. There are the Colonies, they all want plant; there is Northern France to be rebuilt as well as Belgium, and there are only a few chemical potteries in these countries, and they cannot possibly cope with the enormous demand, so I think that here is a chance of a lifetime.

[We are indebted to the Council of the Institution of Gas Engineers for permission to use this Reprint and the loan of blocks.]

X.—The Corrosive Action of Flue Dust on Firebricks.

Communications from the Clay and Pottery Laboratory, Stoke-on-Trent.—No. 88.

By J. W. Mellor and W. Emery.

The experiments indicated in this report were conducted by Mr. Walter Emery. We are indebted to Dr. A. Scott for the microscopic work.

THE influence of the various conditions liable to obtain in industrial furnaces upon the refractories is of the greatest importance. It is so difficult to study these effects on big scale plant under working conditions that very few useful observations have been recorded, and in many cases contradictory or cross results are alone available. There are several explanations for this. It is not always easy to recognise an abnormal condition, because that condition may prevail for a limited period, without making itself obstrusive; but it may perhaps continue long enough to injure seriously the refractory. The abnormal condition may not have been noticed, it is not always easy to see the obvious, and the verdict of the fireman, stoker, or engineer-in-charge is that "everything has been conducted exactly as before," and the only possible explanation of the trouble is that the refractories are thoroughly bad. Many specific examples come to mind where failures have not been the fault of the refractory, although there are other examples where the refractory is itself to blame.

The following experiments describe an attempt to produce abnormal and deleterious conditions. The only possible way to get information on this subject is the method of trial and failure; experiments must be conducted where every baneful condition is under control.

We are here concerned with the action of corrosive flue dust on refractories. The abrasive action of dusts will be discussed on the next report, which is almost ready. There

are many sources of dust in furnaces, coal ash from the producers, dust from furnace charges, etc. It is even possible

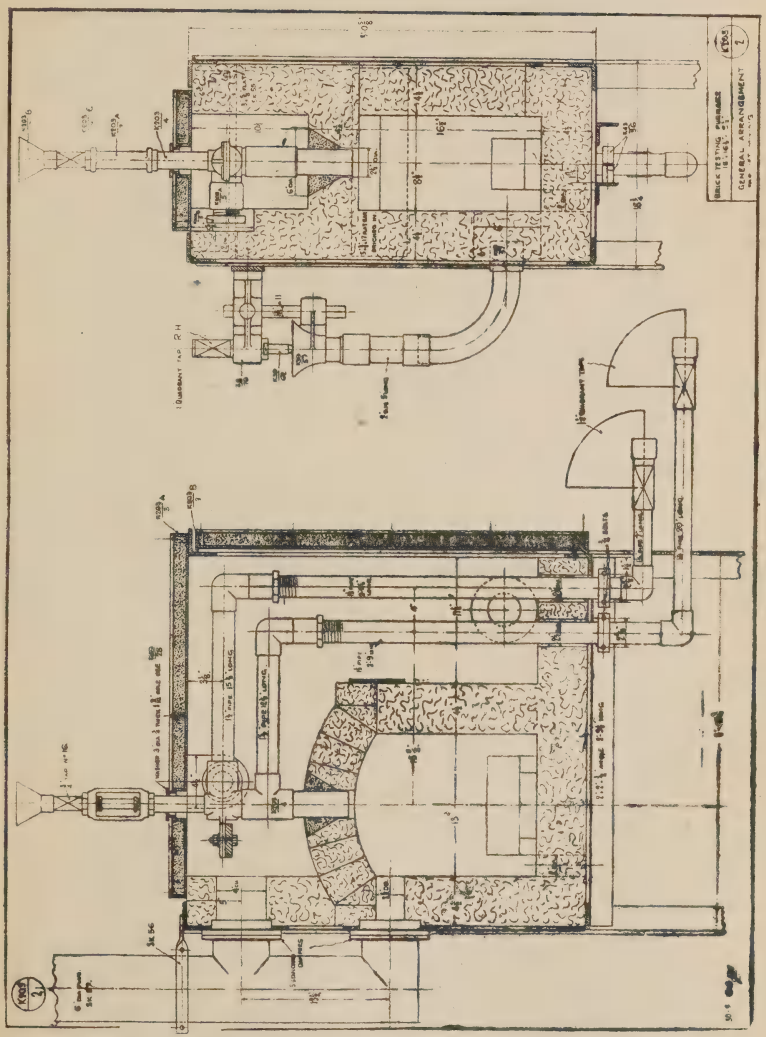


Fig. 1.

to have the action inside a gas retort when the coal is mixed with a relatively minute proportion of limestone. There are two types of limestone—one type is very prone to spurt or

decrepitate when heated, the other type is still. If the former type be rapidly heated in an open crucible on a triangle a ring of white dust will usually be formed on the bench about the feet of the tripod support. If the spurting type of limestone be mixed with the coal a little lime is carried along with the escaping gas, and this readily attacks the inner walls, producing a glazed surface. This repeated charge after charge may shorten the life of a retort very much.

The Furnace.

The largest of the two sections shown in Fig. 1 is a cross-section through the centre of the firing and preheating chambers, the smaller section on the right being a cross-section taken at right angles to the first and showing details of the burner used for preheating purposes. The brick portions (shaded in Fig. 1) are built of fireclay firebricks, and the whole of the furnace is enclosed in an iron casing. The dimensions of the firing chamber are, height 16 in., width 15 in., and depth from back to front 9 in. The temperature during the earlier stages of the test is recorded by a thermocouple inserted through the floor of the furnace. The chimney outlet is controlled by a sliding damper. While the tests are in progress the front of the furnace is partially built up, leaving a circular opening suitable for the focussing of the radiation pyrometer. The heating unit is a "Brayshaw" gas burner, the central tube of which is connected by a piece of glass tubing to the dust feeding device situated at the top of the furnace. The burner, which has an aperture of $1\frac{1}{4}$ in., passes down through the roof of the furnace so that it is immediately over the centre of the kiln bottom.

Town gas at a main's pressure of 3 to 4 inches water gauge together with compressed air at 3 to 4 lbs. per sq. in. is used; the air supply is given by a rotary blower of the positive type; the feed pipes to the burner are $1\frac{1}{2}$ in. in diameter, and each of them is controlled by a quadrant lever. These pipes are led through the preheating chamber where the air and gas supply can be heated if necessary by an auxiliary burner. There is an outlet from this chamber communicating with the chimney and is controlled by a sliding damper. The temperature of the air supply is indicated by means of a thermocouple inserted in the feed pipe near where it enters the burner, and in the experiments so far recorded this was found to range from 350° to 400° C. The dust feeding device consists of a hopper with an internal cone, screw controlled by a small hand wheel,

the principle being the same as that adopted in the cup and cone system used in blast furnaces and gas producers. The lifting of this cone allows the dust to pass through the glass tube into the burner, and thus it becomes mixed with the incoming air and gas. Two bricks are centrally placed in the bottom of the firing chamber at a definite distance from the roof, care being taken to see that the space between the bricks is negligibly small, the front of the kiln is built up as previously described and a known weight of dust is placed in the feeding hopper.

The rate of heating at the start is extremely low, as rapid or irregular heating would cause some types of brick to crack or spall; the temperature is steadily raised to the desired maximum, and this is maintained for half-an-hour. The cone in the dust hopper is raised sufficiently to allow a steady stream of dust to pass into the burner. The glass tube enables the operator to see that the supply is admitted in a proper manner. The flame, with its accompanying dust, is directed downwards on to the surface of the brick. After the whole of the dust has been used the furnace conditions are kept constant for a period of 30 minutes.

The following require special attention:—(1) The distance brick is placed away from the burner, (2) the rate of heating, (3) the maximum temperature reached, (4) the time brick is exposed to the maximum temperature before dust is allowed to enter, (5) the amount of dust, (6) the rate at which the dust is fed on to the brick, and (7) the time brick is kept heated after dust has all been used.

In this furnace the attempt is made to treat a brick so severely that results will be obtained in a few hours which might require months to produce in industrial furnaces. The brevity of life renders it necessary to accelerate the results in this manner in order to satisfy the appetites of committees for reports, and to enable the investigator to see some results before passing his work on to the next generation. No harm is done provided the difference in the conditions with the accelerated results be constantly borne in mind.

The Flue Dust.

In the present series of experiments the following types of dust were employed:—

(1) Boiler flue dust of a slate-brown colour. (2) Boiler flue dust of a brown colour. (3) Deep red-coloured dust from the top of the retort bench of a gas-works. (4) Dust from slag chamber between steel smelting furnace and regenerator. (5) Dust from blast furnace Cowper stove. (6) Bull dog. (7) Red hæmatite ore. (8) Tap cinder. (9) Lime from calcined marble. (10) Lime and common salt—half and half. (11) Salt. (12) Sodium sulphate.

(13) Salt and potash spar—half and half. (14) Sodium silicate and calcium silicate—half and half.

Analyses of most of these dusts are indicated in Table I.

TABLE I.—ANALYSES OF FLUE DUSTS.

	1	2	3	4	5	6	7	8
Silica (SiO_2)... ...	18·33	44·98	20·40	28·76	13·76	15·60	6·80	3·05
Titanic oxide (TiO_2) ...	n.d.	0·82	0·67	0·61	0·13	n.d.	n.d.	n.d.
Alumina (Al_2O_3) ...	2·92	9·50	10·07	8·32	7·12	0·68	1·40	0·35
Ferric oxide (Fe_2O_3) ...	45·34	32·38	55·86	43·60	26·60	8·76	89·94	25·86
Manganese oxide (MnO)	n.d.	n.d.	n.d.	0·99	2·08	n.d.	n.d.	1·40
Magnesia (MgO) ...	2·26	1·18	0·55	0·83	2·16	0·85	Trace	0·40
Lime (CaO)	12·48	3·54	2·25	10·92	9·10	1·30	0·96	0·26
Potash (K_2O) ..	1·40	3·62	2·60	1·74	6·61	Nil	0·33	Nil
Soda (Na_2O) ...	1·30	0·32	0·74	0·32	1·66	Nil		Nil
Loss on ignition ...	4·21	3·51	3·84	0·72	8·32	Nil	Nil	Nil
Phosphoric oxide (P_2O_5)	n.d.	n.d.	n.d.	3·32	1·26	6·42	0·05	0·87
Sulphur trioxide (SO_3)	11·62	n.d.	3·31	n.d.	6·48	0·62	Nil	n.d.
Zinc oxide (ZnO) ...	Nil	Nil	Nil	Nil	15·49	Nil	Nil	Nil
Ferrous oxide (FeO) ...	n.d.	n.d.	n.d.	n.d.	n.d.	65·32	n.d.	67·46

The dusts were all lawned or sieved and only the fraction passing the 60's lawn was used. It was necessary to grind some of the material before lawning, *e.g.*, bull dog. 120 grms. of dust were used in each test.

In order to find a suitable comparison temperature for testing the corrosive action of the flue dusts the bricks *A* and *B* were separately tested with dusts Nos. 1, 2, 3 and 9 at temperatures 1,100°, 1,200°, 1,300° and 1,400° C. The tests were conducted as indicated above. The results of the tests with brick *B* (see below) are indicated in Table II.

TABLE II.

Material	At 1,100°	At 1,200°	At 1,300°	At 1,400°
1	Powder just adherent	Bloated vesicular mass	Fluid mass	Very fluid ; slight corrosion
2	Powder just adherent	Powder beginning to fuse	Semi-fluid mass	Fluid ; no corrosion
3	Sintering just commenced	Melting down	Fused ; no corrosion	Slight corrosion and penetration
9	Dry powder	Slightly melted	Fused ; slight corrosion	Surface badly corroded

Similar remarks apply to brick *A*.

There is no way of indicating the effects of the dust by measurement, and figures 2 to 5 illustrate the action on the surface by photographs.

Fig. 2. Effect of dust No. 2 at 1100°.
,, 3. ,, ,, 1200°.
,, 4. ,, ,, 1300°.
,, 5. ,, ,, 1400°.

Fig. 2.

At temperatures below 1,300° C. the action of the dust is mechanical rather than chemical. The dust begins to act chemically at some temperature exceeding 1,300° C. Obviously each dust will have its own critical temperature, and should be studied as an individual. In this preliminary survey the temperature was kept at 1,400° C.

The Firebricks.

The analyses of the firebricks are indicated in Table II.

TABLE III.—ANALYSES OF THE FIREBRICKS.

	A	B	C	D	E
Silica (SiO_2)	62·00	66 81	94·34	93 52	93·66
Titanic oxide (TiO_2) ...	1·09	1·52	0·36	0·36	0·26
Alumina (Al_2O_3) ..	31·72	27·38	1 96	2·87	2·10
Ferric oxide (Fe_2O_3) ...	3·89	2 19	0 83	0 22	1·30
Magnesia (MgO) ...	0 42	0·35	0·06	0 26	0 06
Lime (CaO)	0·47	0·22	2 04	2·50	1·44
Potash (K_2O)	0 40	1·06	0·28	0·46	0·60
Soda (Na_2O)	0·21	0 69	0·21		0 42
Loss on ignition ...	—	0·17	0·12	0 26	0·22

A was a typical fireclay firebrick. The grog fragments were of medium size (2 to 3 mm. in diameter) and were very hard and compact. The texture was moderately close, but occasionally the cohesion between grog and bond was not particularly good. Some of the bricks had not been well made as they occasionally showed signs of lamination.

B was a typical fireclay firebrick. The grog was coarser than that in *A* (3 to 4 mm. diameter). The texture was much more open and the grog fragments more easily detachable from the bond. *B* had probably been fired at a lower temperature than *A*.

C was a silica brick with fairly coarse grains (up to 6 mm. diameter). The texture was somewhat open and by no means uniform, and the larger grains were often easily detachable from the bond.

D was a very fine-grained silica brick and the grains were of a uniformly small size. The texture was uniform but not very close, and the bond was not particularly good as the brick tended to crumble to fragments under pressure.

E was a close-grained dense silica brick with medium grains (up to 3 to 4 mm. diameter). The larger grains were not easily detachable, and, as was to be expected from the close texture, the fracture was fairly smooth.

The term *erosion* is conveniently applied to the cutting or abrasive action of a dust which is to be discussed in a later report, and corrosion refers to the solvent action of the fused dust on the brick. Severe corrosion is therefore equivalent to slagging. Except where mentioned the temperature was 1,400° C.

The Results with Dust No. 1.

Bricks A and B.—The dust has reacted to some extent with the material of the brick which is fluxed on the surface. The average depth of penetration is about 1 cm. while the corrosion both of grog and bond is appreciable.

Fig. 3.

The Results with Dust No. 2.

Bricks A and B.—The dust has melted to a glass on the surface but has not, in either case, penetrated the bricks to a greater depth than 0·3 cm., nor is there any appreciable corrosion.

The Results with Dust No 3.

Brick B.—The upper surface of the brick is glazed and has been corroded to some extent. There is also considerable

cracking. In cross-section it is seen that the dust has penetrated completely through the brick. The grog has suffered little attack, but the bond is permeated with the dust, the upper layers having melted.

Brick C.—The upper surface is much corroded, but the attack has been confined mainly to the bond and the larger

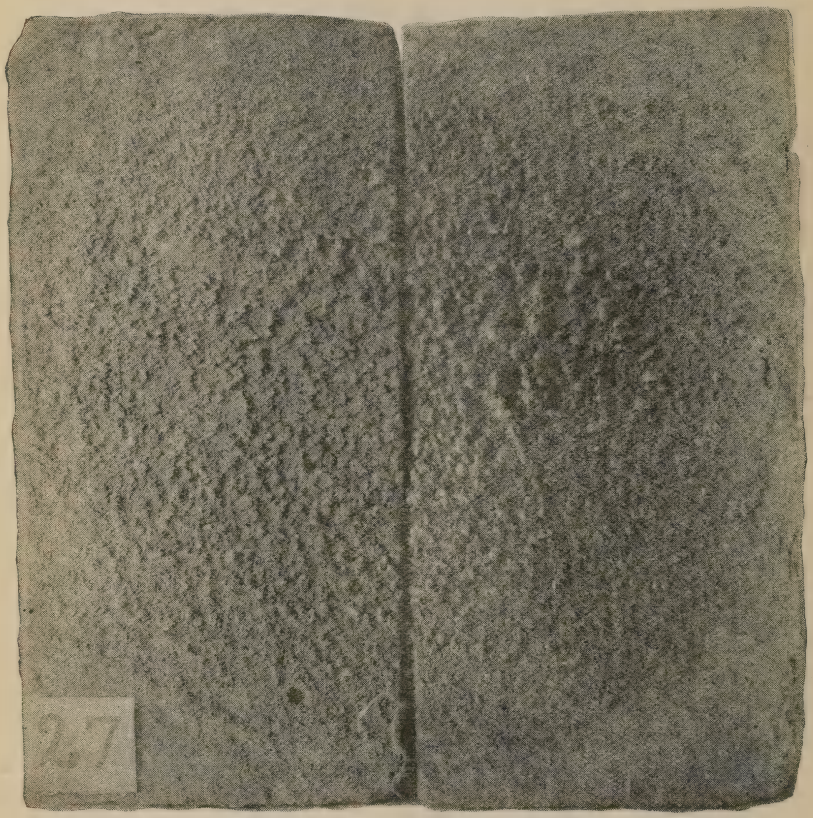


Fig. 4.

grains stand out in relief. The average depth to which the dust has penetrated is 2·5 cm.

Micro-examination.—The dust is confined to the matrix, which has apparently been molten. It consists of cristobalite, magnetite skeletons and minute crystals which are probably rich in silicate of iron. The larger rock fragments have been attacked round the margins, but there is no evidence of penetration of the dust through the fragments. The greater proportion of the

quartz in the latter has been converted to cristobalite, as there is on an average only 12 per cent. of residual quartz (all in the fragments) in the brick, the quantity before the flue attack being about 45 per cent.

The Results with Dust No. 4.

Brick A.—The surface is glazed with slight corrosion, while "runnels" have developed down the sides. The average

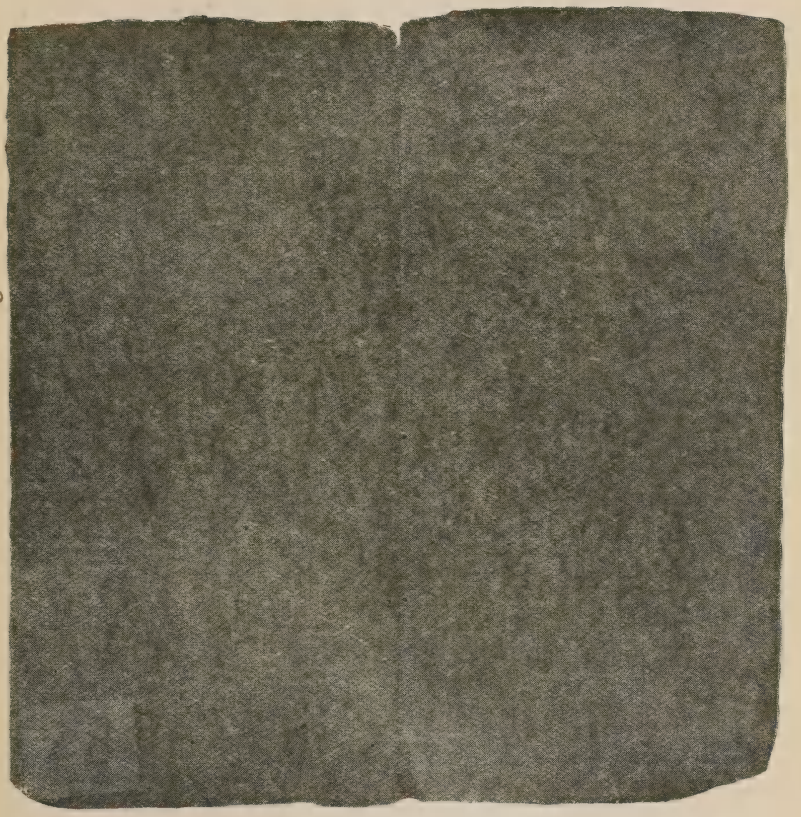


Fig. 5.

depth of penetration is 4 cm. The larger grains have been attacked but are distinguishable. The extent to which the dust has penetrated could not be exactly determined.

Brick C.—The boundary between the attacked and unattacked parts is sharply defined, the average depth of penetration being 2·2 cm. The larger grains stand out in relief and are apparently unattacked, but the upper surface has been corroded.

Micro-examination.—The micro-examination of the upper surface shows that the brick has there been melted completely as no trace of the rock fragments remains, the whole being a uniform mass of cristobalite, with some tridymite, brown to black skeleton crystals and brown opaque glass. In the greater part of the attacked area the larger grains, though completely converted to cristobalite, can be clearly distinguished and are apparently free from foreign material. They have been attacked round the margins, however, as they are generally bordered by an aggregate of skeletal black crystals and cristobalite, arranged in a radial fashion. Beyond this is the brown glass of the matrix, which in places has apparently crystallized.

The Results with Dust No. 5.

Brick B.—The surface is glazed and has suffered corrosion. The dust has penetrated completely through the brick and apparently both bond and grog have been attacked.

Brick C.—Some corrosion has occurred on upper surface, but the larger grains are apparently unattacked and stand out in relief. The average depth of penetration is 3 cm.

Micro-examination.—Micro-examination shows that the effect has been similar to that of dust No. 4 on brick *C*. The dust had reacted with the matrix which had been completely recrystallized. The larger grain still contains about 12—15 per cent. unconverted quartz, which is generally the cores of the original quartz crystals. The larger grains have been attacked round the margins, and in some cases the dust has also penetrated them, being distributed through them in a reticulate fashion, the network possibly having some connection with the structure of the original rock.

The Results with Dust No 6.

Brick C.—Upper surface has been corroded leaving the larger grains in relief. Average penetration is 2·2 cm.

Micro-examination.—The magnetite is confined to the matrix and there is no evidence of reaction between it and the silica. Unchanged quartz is 45 per cent., which indicates that little conversion has occurred during treatment.

Brick E.—There is some corrosion of upper surface, but the larger grains and bond have been corroded uniformly. The average penetration is 2·2 cm.

Micro-examination.—The magnetite is confined to the matrix, but considerable conversion of the quartz in the larger grains has occurred as the residual amount is as low as 30 per cent. Some slight reaction between Fe_3O_4 and the brick has occurred.

The Results with Dust No. 7.

Brick C.—The upper surface has been corroded, but the large grains are almost untouched, as they are white and sharply defined against the black bond. The average penetration is 1·6 cm.

Micro-examination.—The dust has penetrated the matrix, with which it has reacted, forming fayalite (ferrous orthosilicate). The larger grains have

not been penetrated by the dust, nor has much further conversion of the quartz occurred, as there is often 80 per cent. residual quartz in the fragments.

Brick D.—Comparatively slight corrosion had occurred and the dust has penetrated to an average depth of 0·8 cm. In the attacked portion the larger grains cannot be distinguished.

Micro-examination.—In thin section, under the microscope, the iron oxide is seen to have penetrated everywhere, large grains as well as matrix, and to have reacted with the quartz to form ferrous silicate. In the matrix there is an average of 7 per cent. residual quartz, in the larger grains about 30 per cent., indicating that much conversion has occurred during attack.

The Results with Dust No 8.

Brick A.—Surface shows great amount of corrosion, much the greatest in series. The grog has apparently not been directly attacked but has been cut away through the surrounding body being attacked. The average depth of penetration is about 3 cm.

Brick C.—Surface is corroded and the larger grains are in relief. The average depth to which the dust has penetrated is 3 cm.

Micro-examination.—The dust has penetrated the matrix, which has probably been completely fused, as it is an aggregate of cristobalite with some well-formed tridymite, magnetite and fayalite. The larger grains show reaction rims round the margins, but there has been little apparent penetration. The amount of residual quartz in the larger grains has been reduced from over 80 per cent. to about 50 per cent.

Brick D.—A uniform corrosion of the upper surface has occurred. The average depth to which the dust has penetrated is 2·1 cm.

Micro-examination.—Under the microscope the larger grains are seen to have lost, to a great extent, their individuality, and the dust has penetrated everywhere. The amount of quartz has been reduced to 25 per cent., and each quartz grain is isolated in a matrix which has been completely altered to an aggregate of tridymite, cristobalite, magnetite and fayalite. There is a reaction rim round each quartz crystal, which represents the core of an original quartz grain.

The Results with Dust No. 9.

Brick A.—The surface has been glazed and corroded to some extent. The average depth of penetration is 1·5 cm. The grog has only been attacked on the margins of the fragments and the penetration has been mainly by way of the bond.

Brick C.—The upper surface has been corroded leaving the larger grains in relief on a glazed surface. The average depth of penetration is 1·6 cm.

Micro-examination.—No quartz is left in the matrix, which consists of cristobalite, tridymite, and a third mineral which is too minute for identification.

The matrix has probably been molten. The proportion of unaltered quartz in the large grains varies from 20 to 45 per cent., but the mean is about 32 per cent. Each residual quartz crystal (which is small) is the core of an original crystal. The larger grains are easily recognisable as the boundaries are sharp. The lime has reacted first with the matrix, the whole has melted, and the cristobalite has crystallized out on cooling. There has also been reaction between the lime and the larger grains, but this seems to have occurred along the boundaries of the original quartz-grains, *i.e.*, along lines of the cementing material. Over the whole brick the proportion of quartz has been reduced from about 50 per cent. to approximately 12 per cent.

The Results with Dust No. 10.

The temperature in this case was 1,480° C.

Brick A.—The surface has undergone very considerable corrosion and the grog stands out in relief. The average depth of penetration is 1·8 cm. The bond has been fluxed and consequently the grog has been detached.

Brick C.—The surface is glazed with the larger grains in relief. The penetration amounts on an average to about 0·8 cm. The bond has been attacked and fluxed, but the larger grains, while they may have been corroded round their margins, are otherwise unattacked.

The Results with Dust No. 11.

Brick A.—The surface is glazed but there is little corrosion. The average depth of the attack is about 2·5 cm. The grog is apparently untouched.

Brick C.—The surface has been glazed and the bond fused, but the larger grains have not been attacked and they stand out in relief on the corroded surface. The penetration is slight, amounting to 0·4 cm.

The Results with Dust No. 12.

Brick A.—The surface is glazed, but there has been little corrosion. The grog and bond have been attacked uniformly. The average depth of penetration is about 1 cm.

Brick C.—The upper surface is strongly attacked but the salt has not penetrated more than 0·5 cm. The larger grains stand out in relief and are coated with a glaze.

Micro-examination.—The larger grains have not been attacked to any great extent as they still contain about 80 per cent. of quartz. The brick as a whole has still 40 per cent. Any attack which has occurred is round the margins of crystal grains. The matrix has been melted to a glass from which cristobalite and a silicate—presumably sodium—have crystallized out to some extent. Some of the cristobalite probably developed during heating as it is in form of "large" round crystals, the remainder, which is skeletal, developed during cooling. As the edge of the larger grains have been attacked as the boundaries have disappeared and the proportion of quartz gone down to 30 per cent.

The Results with Dust No. 13.

Brick A.—The upper surface is glazed but there has been no corrosion. This surface seems to have had a protective action as the penetration has been slight, averaging 0·6 cm. The grog is unattacked, but the bond has reacted with the dust to form a glass.

Brick C.—The upper surface is well glazed but there has been little penetration into the interior. The bond has first been attacked and the glass so formed has dissolved the larger grains to some extent.

The Results with Dust No. 14.

Brick A.—The surface is well glazed without apparent corrosion. The dust has penetrated to an average depth of 1·5 cm., but there has been little interaction except at the surface where everything had fused to a glass.

Brick C.—The surface has been attacked, the bond apparently reacting with the dust to form a glass which is in process of dissolving the grog. The average depth of penetration is 0·3 cm., but in places the molten material has worked along cracks.

Micro-examination.—A thin section of the surface shows that everything has been fused to a glass out of which cristobalite has been crystallizing. No quartz remains. Further from the surface the remains of larger grains can be distinguished, but these also contain no residual quartz.

General Remarks.

The furnace here indicated appears to be very well adapted to do the work for which it has been designed. Unfortunately it has not been found possible to express the results of the corrosive action of flue dusts in a quantitative manner by weight, by measurement, or by graphic diagram. Photographs of the effect produced by the different types of dust on different types of firebrick are not satisfactory, nor is sufficient reliance to be placed on the depth of penetration to enable it to be offered as a quantitative test.

The photographs, Figs. 6 to 10, illustrate some of the results obtained when the firebricks which have been exposed to the action of dust are cut transversely and the exposed section polished. The broken line shows the depth of penetration. In these particular cases Fig. 6 shows the effect of dust No. 4 on bricks *A* (No. 1) and *C* (No. 2). The area above the broken line represents the depth to which the dust has penetrated. Fig. 7 shows the effect of dust No. 4 on bricks *C* (No. 1) and *D* (No. 2). The broken line in No. 1 indicates the depth to

which the dust has penetrated. In the case of brick *B*, the dust has penetrated everywhere. Fig. 8 shows the effect of dust No. 6 on bricks *C* (No. 1) and *E* (No. 2). The broken lines

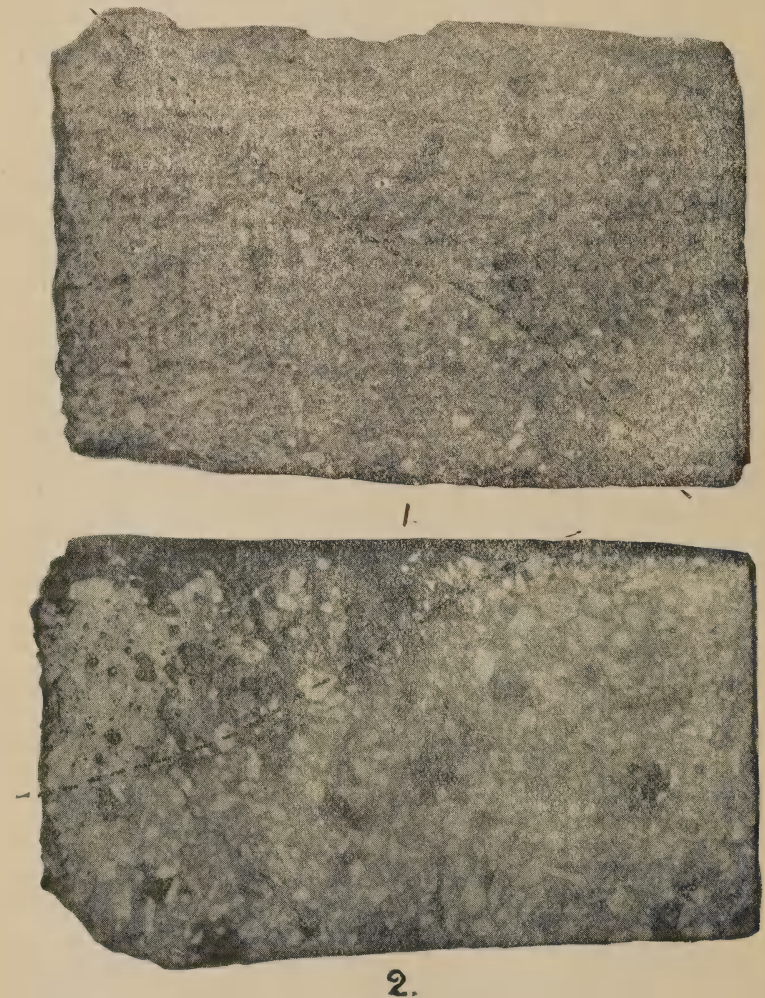


Fig. 6.

indicate the depths to which the dusts have penetrated. Fig. 9 shows the effect of dust No. 7 on bricks *C* (No. 1) and *D* (No. 2). The broken line represents the depth to which the dust has penetrated. Fig. 10 shows the effect of dust No. 8 on bricks

A (No. 1) and *C* (No. 2). The broken lines indicate the depth of penetration of the dust. With two bricks side by side, the attack with a dust liable to corrode or slag the brick is inclined

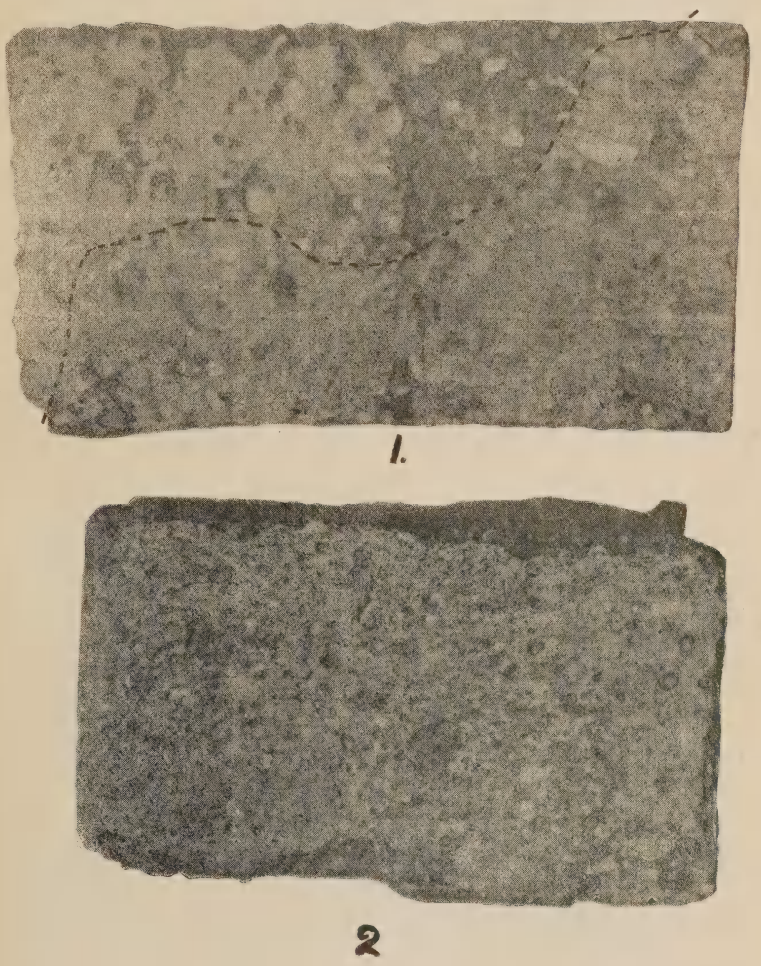


Fig. 7.

to be more vigorous with each brick at the joint than elsewhere.

The scheme in Table IV is an attempt to compress the results obtained into a more compact form. It will be observed

that the various types of corrosive dusts employed can be arranged in following groups:—

(1) Producer ash, flue dust, or coal ash, mainly ferruginous, ranging from those with a high to those with a low proportion of ferric oxide. Some iron oxides alone were also used. These dusts were selected mainly because of the peculiar behaviour of the ferruginous compounds with clays, etc. The fluxing action of ferruginous dusts is greatly facilitated when accompanied by lime.

(2) Alkali chlorides and sulphates.

(3) Lime compounds. These cross with ferruginous lime compounds.

(4) Dusts which readily form fusible silicates.

Except where specified, the atmosphere was mainly oxidizing.

TABLE IV.

Dust	Firebrick	Silica Brick	Fine-grained Silica Brick
Boiler dust high in lime and ferric oxide	*d.P.*; *m.C.*	—	—
Ferruginous boiler dust	*s.P.*; *s.C.*	—	—
Ochreous dust from retort brick ..	*k.P.*; *s.C.*	*d.P.*; *g.C.*	—
Basic slag	*d.P.*; *s.C.*	*d.P.*; *m.C.*	—
Ferruginous dust high in lime ..	*k.P.*; *m.C.*	*d.P.*; *m.C.*	—
Bull dog	—	*d.P.*; *s.C.*	—
Haematite (reducing flame)	—	*d.P.*; *s.C.*	*s.P.*; *s.C.*
Tap cinder	*d.P.*; *m.C.*	*d.P.*; *m.C.*	*d.P.*; *s.C.*
Lime	*s.P.*; *m.C.*	*s.P.*; *m.C.*	—
Lime and salt	*s.P.*; *m.C.*	*s.P.*; *m.C.*	—
Salt	*d.P.*; *s.C.*	*s.P.*; *m.C.*	—
Sodium sulphate	*s.P.*; *s.C.*	*s.P.*; *m.C.*	—
Salt and felspar	*s.P.*; *s.C.*	*s.P.*; *m.C.*	—
Soda-lime glass	*s.P.*; *s.C.*	*s.P.*; *m.C.*	—

In the table *P* = penetration; *C* = corrosion; *s* = slight; *d* = deep; *k* = complete; *m* = medium; *g.C.* = great corrosion or slagging.

This work can be regarded as having opened a big subject. It is possible that the testing of the effect of a given dust on a refractory may be best carried out by moulding mixtures of the dust and the ground refractory, in definite proportions, in the form of cones and determining the fusing point. This plan was followed (*Trans. Cer. Soc.*, **13**, 12, 1913). In general the penetration by the dust is greater in fireclay than in silica firebricks. In most cases the bond is attacked first and the coarser grains last.

In silica bricks the depth of penetration by the dust is generally less the finer the grain. In the fine-grained bricks the coarser grains and the bond are both attacked, while in the coarse-grained bricks the bond is alone attacked to any serious extent. It therefore follows that the bond of a silica firebrick offers the feeblest resistance to the attack of a corrosive slag.

The attack on the coarser grains of silica firebrick varies with the nature of these grains. When there is much cement-

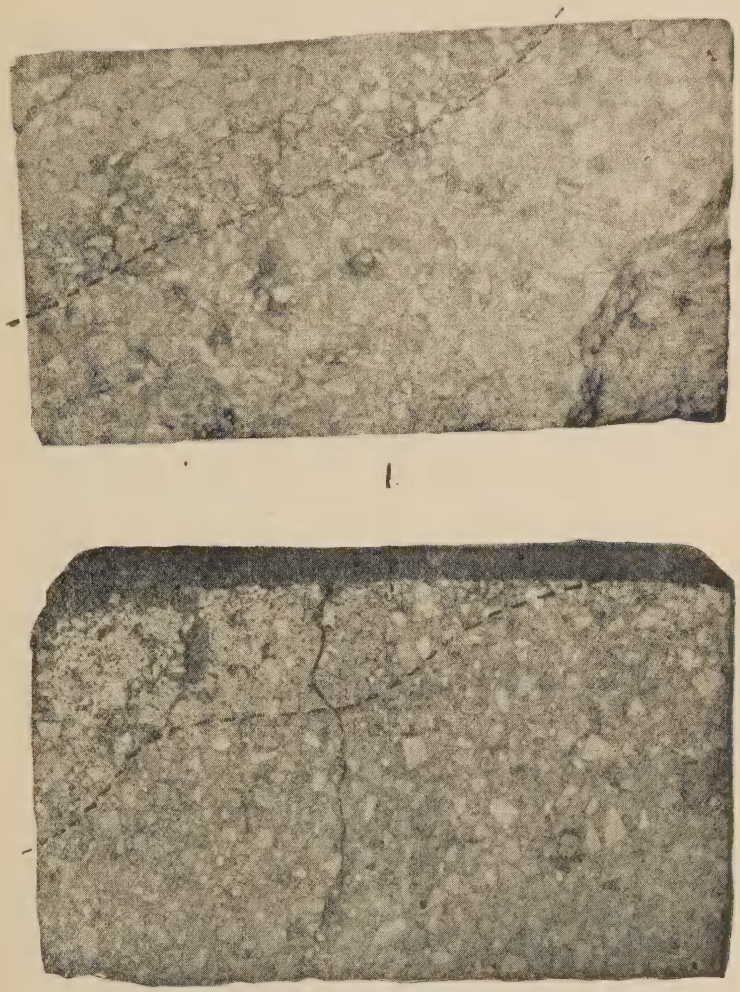


Fig. 8.

ing material between the quartz grains the penetration of the rock fragments by the dust is greater than in the case of a compact rock made up of interlocking grains.

Under oxidizing conditions iron oxide does not corrode silica bricks to any noteworthy extent, but under reducing

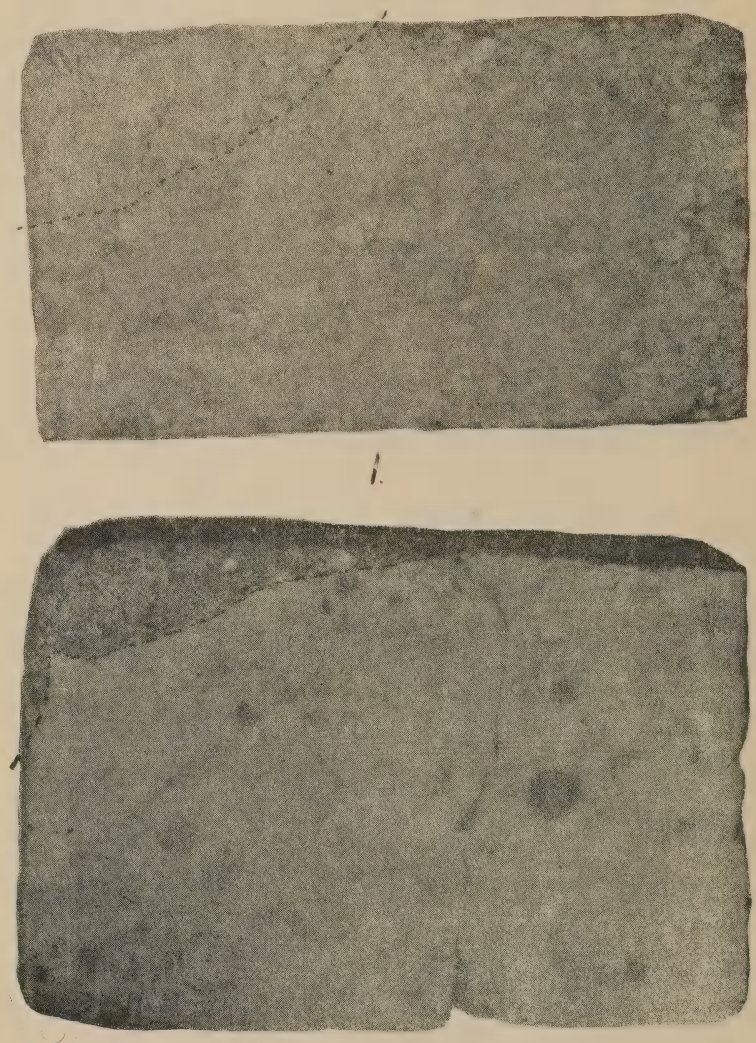


Fig. 9.

conditions ferrous silicate forms and acts as a corrosive flux. In the trials with bull dog the silica bricks are far less attacked

than fireclay bricks; and generally the iron oxides corrode fireclay bricks more than they do the silica bricks.

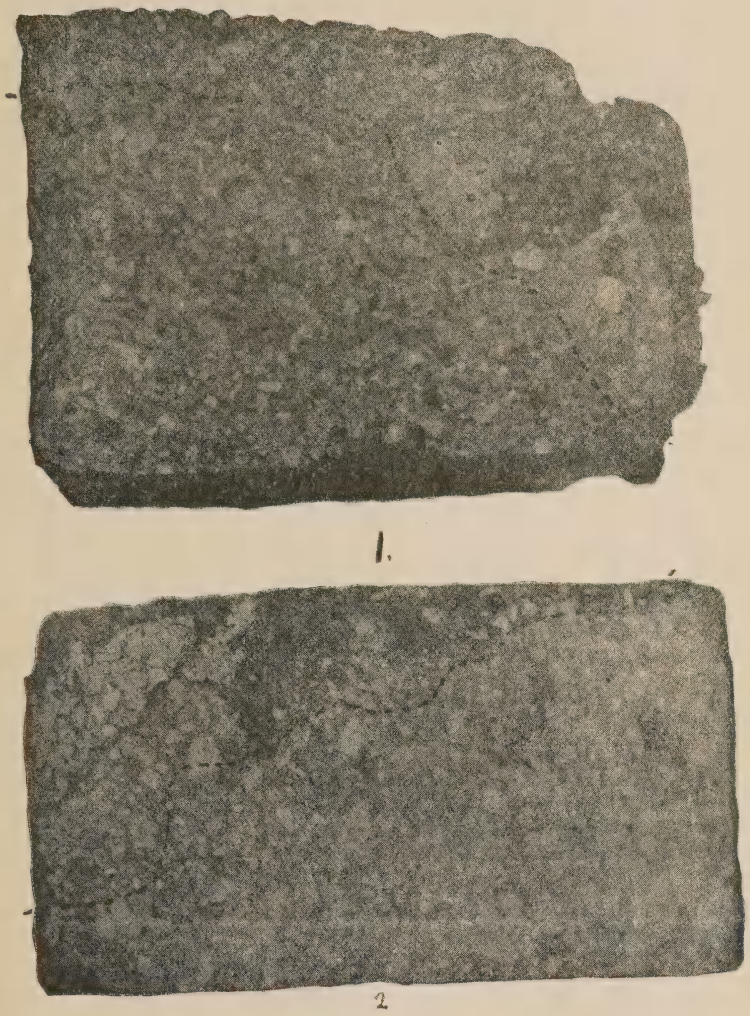


Fig 10.

The dusts apparently exert an influence on the conversion of the quartz into the low specific gravity form or forms even where the coarse grains have apparently not been penetrated. This is possibly in part due to the vapours of the alkalies in

the dust. There is also some evidence that contact with oxide of iron in oxidizing flame hastens the conversion of the quartz.

When the dust is such that it can form a surface glaze the brick is protected from further attack, or rather the subsequent rate of attack is considerably diminished. This corresponds with a well-known practice of smearing a glaze mixture on the face of the brickwork in certain kilns. If the surface glaze be fluid enough and in such a position that it can flow to a lower level these remarks do not apply, for the brick is rapidly eaten away as soon as the glaze begins to drip. The attempts to give the brick a resistant face by fusing the surface by means of a blowpipe flame are not satisfactory because the surface skin peels off.

DISCUSSION.

Mr. W. T. GARDNER:—I have had a fair experience with the action of flue dust on various materials, but it is difficult to lay down any definite conclusions. One can only compare the resistance of various firebricks.

I have found that the action of flue dusts on fireclay material is far greater than the action of flue dust on silica material. Naturally bricks that have the lowest percentage of fluxes present suffer least with regard to the fluxing action of dusts.

I once had rather an interesting experience with regard to boiler linings. We had a boiler the lining of which was out in a few weeks. We were using Stourbridge material, which was cutting away in three to four weeks to the extent of 4 in. I worked at the problem and substituted some pure clay bricks burnt very hard. I found that those bricks lasted much better and had more than double the life of the more porous bricks of Stourbridge material. I take it that the liquid slags were not penetrating the surface to the same extent.

XI.—The Standardization of Tests for Refractory Materials (Part II.)

Report of the Committee, consisting of Prof. J. W. Cobb, B.Sc., Dr. H. G. Colman, Major C. W. Thomas, Messrs. F. H. Brooke, W. J. Brooke, A. Cliff, J. Allen Howe, Cosmo Johns, W. J. Jones, B. Moore, D. J. Pinkerton, W. J. Rees, and Dr. J. W. MELLOR, Hon. Sec.

PROVISIONAL SPECIFICATION.

XII.—The Grading of Clays, etc., according to the size of grain.

IT is the object of the so-called mechanical analysis to sort the particles which make up the clays into groups, so that the sizes of the particles in each group range between certain specified limits. In some cases the ordinary sieve analysis will suffice, but the finer particles are outside the range of sieves and lawns, and it happens that in the finer-grained clays by far the larger proportion passes through the finest lawns.

Sieve Analysis.

For testing purposes it is well to use lawns with a standard gauge since the sizes of the apertures in the different lawns supposed to be of the same dimensions are indefinite, vague, and dependent on the mode of manufacture. The standard lawns established by the Institute of Mining and Metallurgy are suitable for the purpose. The numbers and dimensions of the lawns are indicated in Table I.

The sieve process works best if the material be slopped and the fine stuff washed through each lawn. The residue on each lawn is then dried and weighed. With the more coarsely ground materials, such as are commonly used for the manufacture of silica bricks, a set of three lawns, say No. 5, No. 50, and No. 120, will suffice. The result can be expressed:—

	Grain size	Percentage amount
Amount which stays on lawn No. 5	Over 2·54 mm.	—
Amount which passes No. 5 and stays on No. 50 ...	Between 2·54 and 0·254 (*i.e.*, 0·1 and 0·01 in.)	—
Amount which passes No. 50 and stays on No. 120 ...	Between 0·254 and 0·091 mm. (*i.e.*, 0·01 and 0·0041 in.) ...	—
Amount which passes No. 120	Less than 0·091 mm. (*i.e.*, ·0041 in.)	—

TABLE I.—THE I.M.M. STANDARD LABORATORY SIEVE SCALE.

Mesh, *i.e.*, apertures per linear inch	Diameter of wires		Diameter of aperture		Screening area per cent. holes
	Inch	Mm.	Inch	Mm.	
5	0·1	2·540	0·1	2·540	25·00
8	0·0625	1·587	0·0625	1·587	24·60
10	0·05	1·270	0·05	1·270	25·00
12	0·0416	1·059	0·0416	1·059	24·92
16	0·0313	0·795	0·0312	0·792	24·92
20	0·025	0·635	0·025	0·635	25·00
30	0·0167	0·424	0·0166	0·421	24·80
40	0·0125	0·317	0·0125	0·317	25·00
50	0·01	0·254	0·01	0·254	25·00
60	0·0083	0·211	0·0083	0·211	25·00
70	0·0071	0·180	0·0071	0·180	25·00
80	0·0063	0·160	0·0062	0·157	24·60
90	0·0055	0·139	0·0055	0·139	24·50
100	0·005	0·127	0·005	0·127	25·00
120	0·0041	0·104	0·0042	0·107	25·40
140	0·0036	0·091	0·0036	0·091	25·00
150	0·0033	0·084	0·0033	0·084	24·50
160	0·0031	0·079	0·0031	0·079	25·00
170	0·0028	0·071	0·0028	0·071	25·00
180	0·0025	0·063	0·0025	0·063	25·00

Ordinary lawns of an equivalent size will probably suffice for works' practice, and it is possible that in particular cases a set of three other sizes might be more convenient. All depends on the standard coarseness of the material employed in the works.

Elutriation Analysis.

With the finer ground materials, *e.g.*, ground flint, and also clays, the sizes just recommended are quite inadequate, because by far the largest portion passes through the 120's lawn. Indeed, in many cases by far the largest fraction will pass through the finest lawn available. Consequently, where the grain size of the clay or fineness of the grinding of flint, etc., is desired, it is necessary to adopt other methods of grading. The so-called elutriation process is perhaps the most convenient method.

It is first necessary to disintegrate the particles which are clotted together, otherwise a clot or aggregate of fine particles will behave like one big one. In some cases it is sufficient to rub the clay gently with water by means of a rubber pestle. The grains must not be broken by crushing or grinding. The natural physical condition of grains must be modified as little as possible. Some clays are ready for treatment as they come from the pit, others are of stone-like hard-

ness. In the latter case weathering may or may not disintegrate the clay. If the clays resist weathering elutriation can be a test only of the fineness of the grinding of the clay, and can give no information as to the natural grain of the clay.

The use of acids to facilitate disintegration should be avoided wherever possible because of their action on the zeolitic minerals in the clay. The presence of soluble salts in the clay, *e.g.*, calcium sulphate, may make the mechanical analysis all wrong, because these salts flocculate particles so that a clot of small granules behaves as if it were one big one.[1] Thus the addition of 0·1 gram of calcium sulphate to 250 c.c. of a mixture of china clay and water changed the fraction which subsided in 25 minutes from 6·1 to 10·6 per cent., and the presence of 0·1 gram of sodium chloride changed the amount from 6·1 to 8·6 per cent. Hence, it is important with some clays to wash out the soluble salts and to employ distilled water for the subsequent work. If ordinary tap water be employed the results for the finest fraction of the fine-grained clays will be lower in towns where hard water is used than in towns where soft water is used. Tap water can be used for testing the fineness under ordinary works' conditions on the assumption that the water is constant, but where a variety of clays have to be compared it is advisable to use distilled water.

Preliminary treatment of sample.—Ten grams of clay are thoroughly mixed with distilled water and shaken in one of the regular types of shaking apparatus. The water should be mixed with 1 or 2 per cent. of ammonia or ammonium carbonate. Four hours' shaking will suffice with some clays, others require a longer treatment. Too much shaking will naturally wear down the coarse grains. The disintegrated clay is then passed through a 120's lawn, and the residue washed with distilled water. Preserve the washings. The residue on the lawn is then dried at 110° and weighed.

The washings may now be treated in a vessel called an elutriator. In this apparatus the clay is subjected to a stream of water of definite velocity.

Principles of the elutriation process.—A given particle in still water will descend to the bottom at a rate which depends principally on its size, shape, specific gravity, and the nature of the surface. If the water be made to ascend at the same speed as the particle descends in still water it will remain stationary. If the speed of the water current be increased beyond this limit the particle will be carried upwards with the stream. There is therefore a limit to the size of a spherical

1 The coagulating effects of soluble salts and of ordinary tap water are usually overlooked or ignored.

and grain which will be carried off by a current of definite speed and above which the grain will sink downwards against the ascending current. By using different speeds, and measuring the maximum size of grains carried off, it is possible to separate a given powder into a number of fractions containing particles above and below a certain limiting size.

E. Schöne[1] found empirically that if V represents the velocity of a stream of water in millimetres per second, the maximum diameter, D, of spherical sand grains—sp. gr. 2·65—which will just move with the stream can be represented by the expression:—

$$D = 0{\cdot}314\ V^{0{\cdot}636} \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

provided the velocity of the stream is between 0·1 and 12 mm. per second. These are the limits usually employed in the mechanical analysis of clays, and hence Schöne's empirical formula may be taken as a standard of reference, whence it follows that when

Velocity = 0·166, 0·717, 1·460, 3·020 mm. per sec.
Diameter = 0·010, 0·025, 0·040, 0·063 mm.

If we are dealing with specific gravity, S, appreciably different from 2·65, (1) becomes:—

$$D = 0{\cdot}0518\frac{V^{0{\cdot}636}}{S-1} \quad \ldots \quad \ldots \quad (2)$$

In order to obtain fractions with the limiting sizes suggested above the corresponding velocities can then be calculated from the expression:—

$$V = 104{\cdot}7(S-1)^{1{\cdot}57}D^{1{\cdot}57} \quad \ldots \quad \ldots \quad (3)$$

These formulæ agree very closely with results obtained by actual measurement.

Example.—What is the velocity required in the elutriation of a lead frit, sp. gr. 5·2, in order to furnish particles with the diameters 0·01 mm.? Answer:—Log $V = 1{\cdot}1127$; so that when $D = 0{\cdot}01$ $V = 12{\cdot}96$. Thus:

$$\begin{aligned}\text{Log } V &= \log\ 104{\cdot}7 + 1{\cdot}57\ \log\ (S-1) + 1{\cdot}57\ \log\ D.\\ &= \log\ 104{\cdot}7 + 1{\cdot}57\ (\log\ 4{\cdot}2 + \log\ 0{\cdot}01).\\ &= 2{\cdot}0202 + 1{\cdot}57\ (0{\cdot}6232 + 2{\cdot}7993).\\ &= 2{\cdot}0202 + 1{\cdot}0925 = 1{\cdot}1127 = \log\ 12{\cdot}96.\end{aligned}$$

Fitting up the elutriator apparatus.—There are several forms of elutriator on the market. The Schöne form with an extended conical neck has been fairly popular. It is, however,

[1] E. Schöne, *Ueber Schlämmanalyse und einer neuen Schlämmapparat*, Berlin, 1867.

ERRATUM.

Page 254.

Formula (1) should read: $D = 0{\cdot}0314\ V^{0{\cdot}636}$ instead of $D = 0{\cdot}314\ V^{0{\cdot}636}$

Formula (3) should read: $V = 104{\cdot}7(S-1)^{1{\cdot}57} D^{1{\cdot}57}$ instead of $V = 104{\cdot}7(S=1)^{1{\cdot}57} D^{1{\cdot}57}$

rather fragile and easily broken, and so also is the manometer. If the grading here recommended be used the gauge of Schöne's apparatus is not required, and a tube like that shown in the

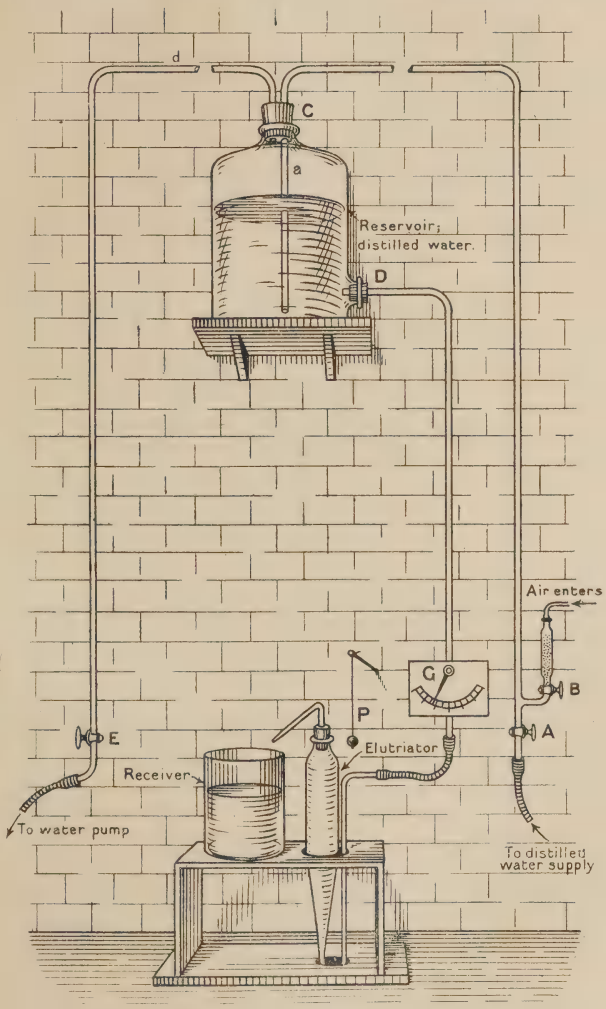


Fig. 1. Apparatus for Elutriation with Distilled Water.

figure will suffice. The elutriator is connected to the water supply by a piece of stout rubber tubing. It is usual to connect the elutriator to a tank fed from the town supply, and maintained at a constant level by means of a ball-cock. If distilled

water be used, and it is strongly recommended for comparison work, the arrangement illustrated in Fig. 1 will feed the elutriator with distilled water at a constant pressure.

A 20-litre aspirator bottle is fitted with a rubber stopper *C*, and two glass tubes. One tube, *a*, passes to the bottom of the bottle, and the opposite end dips into the laboratory stock of distilled water. A two-way stopcock *A* is placed conveniently, and a side-tube is fitted with a stopcock *B* and a cotton wool filter to remove dust from the air which passes through. The other tube *d* passes to the filter-pump and it has a stopcock, *C*, fitted in a convenient place. The tubulure *D* is closed by a one-hole rubber stopper and fitted with a tube to lead water from the bottle to the elutriator. The indicator stopcock is not required unless a system of fractionation be employed other than that indicated below. This tube is connected with the indicator stopcock, *G*, for regulating the velocity of the water flowing through the elutriator. To fill the reservoir bottle with distilled water close the stopcocks *G* and *B*; connect the tube *a* with the distilled water bottle; connect *d* with the filter-pump, and distilled water will pass into the reservoir. When the reservoir is full, close *A*, open *B*, and stop the connection with the filter-pump at *E*, when the water has been cleared away from the tube *a*. When the stopcock *G* is open, the water will run from the reservoir at a constant pressure since the reservoir acts as a Marriotte's bottle.

The elutriator is supported on a wooden stand as shown in the diagram. With the stopcock and pointer a simple exit tube alone is necessary, and the clumsy manometer of Schöne's apparatus can be omitted. The outflow nozzle of the stopcock may have an opening about a millimetre in diameter. The stand is arranged to support a large cylinder as receiver to collect the outflow. The exit nozzle, etc., can now be standardized.

The velocity of the water in the elutriator is not always sufficient to keep the sediment in suspension, and clots of clay may collect in the narrow leg of the elutriator. This may be prevented by introducing sufficient mercury, or small shot No. B or BB, to fill about 2 or 3 cm.

The standardization of the elutriation apparatus.—Each elutriator has its own constants which must be determined and the proper adjustment made. To graduate the cylindrical portion of the elutriator fill the conical portion with water and mark the lower level of the meniscus with a piece of gummed paper. Run in 20 c.c. of water from the burette, again mark the lower level of the meniscus and measure the rise in the level

of the dater due to the addition of the 20 c.c. water. Repeat the additions and measurements until the sides at the top begin to curve inwards. This is shown by an increased rise in the level of the liquid when 20 c.c. of water are added. The addition of each 20 c.c. should cause the same rise in the level of the liquid in the cylindrical portion. If there be large deviations the elutriator is not a good one; if the deviations be near the top and bottom alone these readings should be rejected

In one elutriator the addition of every 20 c.c. of water produced a rise of 8 mm. We know that the volume of a cylinder is equal to the area of the cross section multiplied by the height of the cylinder. Hence, 100 = area of cross section $\times 4$; or, area of cross section = 25 sq. cm.

To get the speed, V mm. per sec., it is necessary to remember that the velocity of a given stream represents the number of millimetres of a given column of water which flows past a given point in the cylindrical portion of the elutriator per second, and the volume v of outflow per second is equal to the velocity, V mm. per second, multiplied by the sectional area 25 sq. cm. or 2,500 sq. mm. Hence the volume of water v in millimetres per second is 2,500 V or

$$\text{Velocity} = 0{\cdot}0004\ v \text{ mm. per sec.}$$

It is then necessary to find the volume of water, v, in cubic millimetres per second which flows from the elutriator for a dozen different positions of the index on the dial of the stopcock by collecting the outflow in a measuring cylinder and noting the time. The outflow, v cubic millimetres per second is then calculated from, and the corresponding value of v is computed from (2) above. The following represents a few results, with an index stopcock and the elutriator.

v =	3968·3	2898·5	1092·8	685·0	329·0 cub. mm. per sec.
V =	1·59	1·16	0·44	0·27	0·13 mm. per sec.
1 =	3·8	3·9	4·3	4·6	5·0

Corresponding values of V and the index, or manometer, reading 1, are plotted on squared paper. The curve, Fig. 2, then indicates at a glance the position of the stopcock, or manometer, required for any given velocity.

The Classification of the Fractions in Mechanical Analysis.

The question has to be settled: What are the best fractions to use? The elutriator does not satisfactorily separate fractions with particles with diameters less than 0·01 mm. This is usually the largest proportion of this fraction in the better class clays,

and in finely ground materials. The following fractions have been in use for some years:—

TABLE II.—PROPOSED FRACTIONS FOR GRADING FINELY GROUND MATERIALS, FIRECLAYS, ETC.

Maximum velocity mm. per sec.	Extreme diameters mm.	Average diameters mm.
0·18	Below 0·01	0·0063
0·30 (200's lawn)	0·01 to 0·063	0·042
Residue (120's lawn)	0·063 to 0·107	0·087

The advantage of this classification is that two of the three fractions can be separated by sieves, and only one fraction is

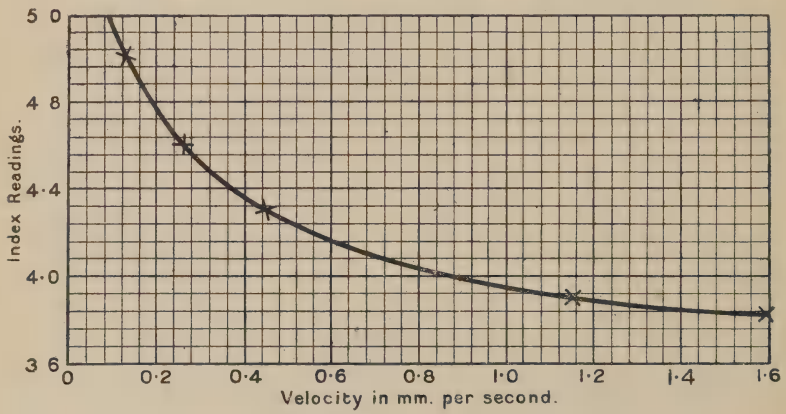


Fig. 2

left for the elutriator. The elutriation can then be conducted overnight. For the elutriation, therefore, the fine stuff which passes a 120's lawn is washed through a standard 200's lawn directly into the elutriator. The washed residues on the lawns are dried and weighed.

The Elutriation.

If the classification of fractions here recommended be adopted the index-stopcock is not needed, since it is sufficient to suspend a weight by means of a string about 10 in. long so as to form a kind of pendulum (*P*, Fig. 1), and to arrange matters so that a drop of water falls from the out-flow nozzle of the elutriator into the receiver with each swing (half a complete oscillation) of the pendulum. This is very convenient

method of testing if the water is flowing through the elutriator at the right speed.

The elutriation is continued until the outflow is quite clear and free from clay. The residue in the elutriator is washed away into a basin, and then dried and weighed. Consequently weighings are now available representing (i) the weight of the samples (ii) the weight of the residue on the 120's lawn, and (iii) the weight of the residue which passes 120's lawn and stays on a 200's lawn.

The finest fraction is often estimated by difference. All the errors of experiment in the other determinations are then accumulated in this fraction. There is unfortunately a large volume of water with fine clay in suspension, and it is usual to make this up to a definite volume and evaporate an aliquot portion—about 200 c.c—to dryness in a weighed dish, and multiply the result by the necessary factor to represent the total solid matter in suspension. In taking the aliquot portion it is important that the liquid be thoroughly agitated. It is best to take three or four portions at different depths and treat each separately. The mean result is taken as representative of the whole. The final results can be expressed in percentages

Surface Factor.

It is often difficult to compare the fineness of two or more clays. For example, if a powder has the three fractions 45, 10, 45 per cent., and another the fractions 35, 25 and 40 per cent., which is the finer powder. A method has been in use for many years in which the fineness is expressed in terms of what is called the *surface factor*. In this system the surface area of the particles—assumed to be spherical—in each group is computed, and the surface area of the particles in all the groups, added together, make the so-called surface factor. The principles are discussed in the *Transactions of our Society* (**9**, 94, 1910), and it will therefore be sufficient to give the method of computation alone for the case where the fractions have all the same specific gravity, and where the three fractions indicated above are employed.

Let W_1, W_2, and W_3 denote the respective weights of the fractions 1, 2, and 3 per unit weight of powder, and d_1, d_2, and d_3 the corresponding average diameters of the grain in fractions 1, 2, and 3 respectively, the surface factor then reduces to:

$$\text{Surface factor} = 359W_1 + 53{\cdot}9W_2 + 26{\cdot}0W_3.$$

Here W_1 represents the weight per unit of the finest fraction, W_3 the coarsest.

Example.—What is the surface factor for sand, sp. gr. 2·65, when these fractions in unit mass have been obtained:

Mean diameter ...	0·0063	0·042	0·087 mm.
Weight	60	25	15 per cent.

Here the surface factor is 233, since $359\times0{\cdot}6+53{\cdot}9\times0{\cdot}25+26{\cdot}0\times0{\cdot}15=233$.

XIII.—The Corrosive Action of Flue Dusts on Refractories.

The Institute of Gas Engineers' report on the corrosive action of flue dusts on firebricks has shown that with our present knowledge there is no satisfactory method available for *measuring* the corrosive action of flue dust under conditions approximating to those which obtain in practice. It is, however, possible to observe the effect *qualitatively* in a furnace of the type shown in Fig. 3. In this furnace the temperature and atmosphere of the furnace are under control, and the effect of any type of dust on any type of firebrick can be observed. The results obtained do not lend themselves to measurement, although comparable results can be obtained with a given set of bricks.

The furnace.—The largest of the two sections shown in Fig. 3, is a cross-section through the centre of the firing and preheating chambers, the smaller section on the right being a cross-section taken at right angles to the first and showing details of the burner used for preheating purposes. The brick portions (shaded in Fig. 3) are built of fireclay firebricks, and the whole of the furnace is enclosed in an iron casing. The dimensions of the firing chamber are, height 16 in., width 15 in., and depth from back to front 9 in. The temperature during the earlier stages of the test is recorded by a thermo-couple inserted through the floor of the furnace. The chimney outlet is controlled by a sliding damper. While the tests are in progress the front of the furnace is partially built up, leaving a circular opening suitable for the focussing of the radiation pyrometer. The heating unit is a "Brayshaw" gas burner, the central tube of which is connected by a piece of glass tubing to the dust feeding device situated at the top of the furnace. The burner, which has an aperture of $1\frac{1}{4}$ in., passes down through the roof of the furnace so that it is immediately over the centre of the kiln bottom.

Town gas at a main's pressure of 3 to 4 inches water gauge together with compressed air at 3 to 4 lbs. per sq. in. is used; the air supply is given by a rotary blower of the positive type; the feed pipes to the burner are $1\frac{1}{2}$ in. in diameter, and each of them is controlled by a quadrant lever. These pipes are led through the preheating chamber where the air and gas supply can be heated if necessary by an auxiliary burner.

There is an outlet from this chamber communicating with the chimney and is controlled by a sliding damper. The temper-

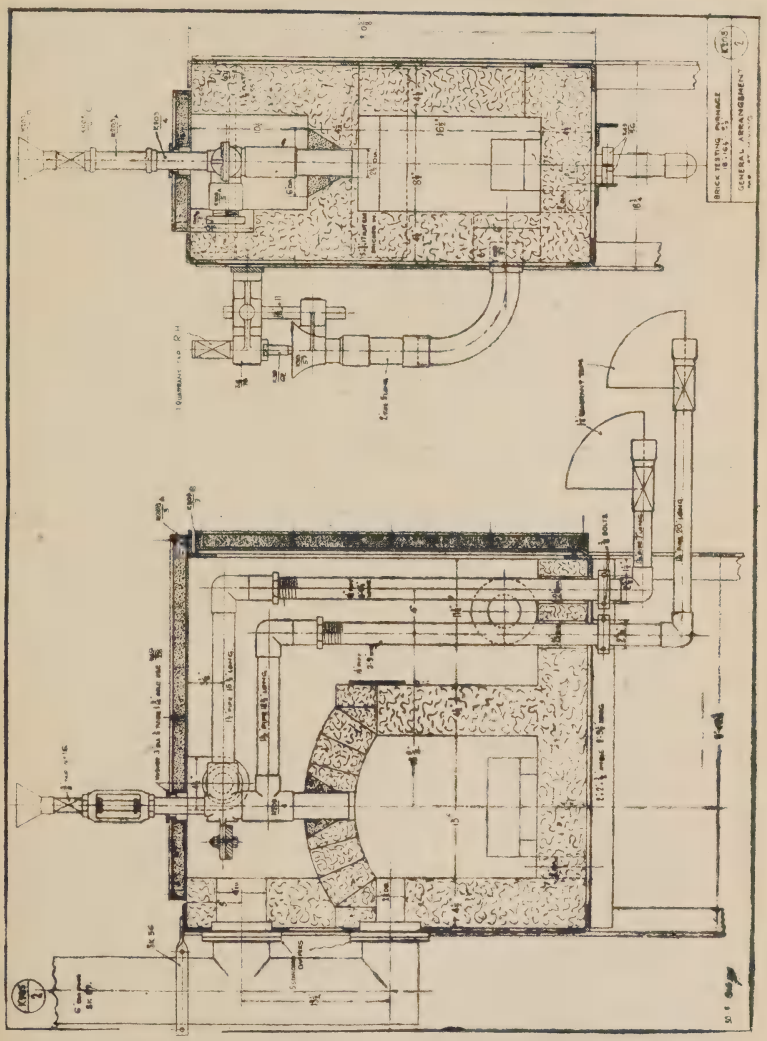


Fig. 3.

ature of the air supply is indicated by means of a thermocouple inserted in the feed pipe near where it enters the burner, and in the experiments so far recorded were found to range from

350° to 400° C. The dust feeding device consists of a hopper with an internal cone, screw controlled by a small hand wheel, the principle being the same as that adopted in the cup and cone system used in blast furnaces and gas producers. The lifting of this cone allows the dust to pass through the glass tube into the burner, and thus it becomes mixed with the incoming air and gas. Two bricks are centrally placed in the bottom of the firing chamber at a definite distance from the roof, care being taken to see that the space between the bricks is negligibly small, the front of the kiln is built up as previously described and a known weight of dust is placed in the feeding hopper.

The rate of heating at the start is extremely low, as rapid or irregular heating would cause some types of brick to crack or spall; the temperature is steadily raised to the desired maximum, and this is maintained for half-an-hour. The cone in the dust hopper is raised sufficiently to allow a steady stream of dust to pass into the burner. The construction of the burner enables the temperature to be regulated within the limits ± 10° C. The glass tube enables the operator to see that the supply is admitted in a proper manner. The flame, with its accompanying dust, is directed downwards into the surface of the brick. After the whole of the dust has been used, the furnace conditions are kept constant for a period of 30 minutes.

The points requiring attention are: (i) The distance brick is placed from the burner; (ii) the rate of heating; (iii) the maximum temperature reached; (iv) nature of flame (oxidizing or reducing); (v) the time brick is exposed to the maximum temperature before dust is allowed to enter; (vi) the amount and grain-size of dust, and rate at which it is fed on to the brick; (vii) space between the brick: there is a tendency for dust to penetrate from the side, and (viii) the time brick is kept heated after the dust has all been used.

A discussion of some results with this furnace will be found in the *Transactions of our Society*, **18**, 230, 1918).

DISCUSSION.

Mr. CROOK:—I think there is room for plenty of useful discussion on this subject before any definite recommendations are decided upon. It seems desirable to get some simple standard method of procedure such as you aim at in this paper, but I think a much simpler statement is possible than the one here given

I prefer avoidance of questions and think that correlation of speeds and sizes should be reached by actual observations. After all one never gets spherical particles. I did a lot of

careful work some years ago on the 0·01 mm. limit, and came to the conclusion that 0·15 mm. per sec. was about as near the truth as one could get by actual measurement.

Grading limits are well worth discussing, and it should be possible to reach some uniformity of practice, but it seems quite undesirable to make the limits depend on convenient sieve sizes.

I am in favour of elutriating everything below and including 0·1 mm. diameter, mainly because fine sieves are difficult to operate with—they hold particles in their meshes, and they are sloppy and liable to error in use.

I think a simple water column should be used for a pressure-gauge, and I prefer to standardize speeds in terms of water levels and nozzle apertures only.

If you wish to separate at the 0·1 mm. limit by means of a sieve, and wish to subdivide the finer part by elutriation in two grades I would suggest that 0·01 and 0·05 are convenient limits, and leave anyone who chooses to do so to insert a 0·025 limit. I am strongly in favour of differentiating sand, silt and mud as three big groups, and subdividing them uniformly, thus:

Sand	..	1 mm. to 0·1 mm.
Silt	..	0·1 ,, to 0·01 ,,
Mud	..	< 0·01 ,,

Each of these can be subdivided into 3 as indicated above.

XII.—Zirconia: Its Occurrence and Application.

By H. C. MEYER, Philadelphia.

LITERATURE on the technology and application of zirconium oxide has been amazingly stimulated by the war, not only in the United States but also in England. Probably we would even be more surprised at the applications which have been developed in Germany during the last four years, but unfortunately very little information of an authentic character has been available. As far back as the year 1913, Krupp's of Essen were experimenting with zirconia, presumably in the hope of developing its use as a steel-hardening agent. At the same time, several German chemical manufacturers were producing pure white zirconium oxide free from iron, titania and silica, at prices varying from 60c. to 75c. per kilogram. In 1915, the writer spent much time in Brazil investigating the zirconia deposits, and in a sojourn of over a month in the Caldas area, learned from personal conversation with various well-informed landowners, that there had been an attempt by certain German interests to form a monopoly. Fortunately the sentiment in Brazil in the very beginning of the war was strongly pro-ally, and any marked activities on the part of German interests were not only frowned upon by the Brazilian Government but also by the public in general. A local representative of German interests became involved in certain legal difficulties in regard to the title of certain zirconium ore deposits and was subsequently recalled to Germany.

Brazilian Zirkite Deposits.—Throughout this paper, wherever the word "zirkite"[1] is employed, it is understood that it is not as the name of any particular mineral but merely to designate the commercial ore of zirconium such as that furnished by the deposits near Caldas, being essentially a mixture of Brazilite, zircon, and a new and unnamed zirconium silicate. This new zirconium silicate was under investigation by Dr. Orville A. Derby, former chief of the Brazilian Geological Survey, at the time of his death.

There are but few commercial deposits of the unusual ores which present more interesting geologic as well as economic features than do the deposits of natural zirconium oxide in

1 A trade name registered in the U.S. Patent Office by the Foote Mineral Co. of Philadelphia.

Brazil. The Caldas region (visited in 1915 by the writer), in which these zirconia deposits occur, is situated partly in the state of Minas Geraes and partly in the state of Sao Paulo, approximately 130 miles north of the city of Sao Paulo. It is a mountainous plateau, the main elevation of which is about 3,600 feet. The surface is undulating, presenting differences in altitude of from 300 to 600 feet. The whole area is bounded on all sides by ridges rising abruptly from 600 to 1,200 feet above the general level and forming a roughly elliptical enclosure with a major axis of approximately 20 miles in length and a minor axis of 15 miles. This peculiar arrangement of the higher ridges is very significant when coupled with the fact that the predominant rock of the plateau is a phonolite and with the presence of highly mineralized thermal water of considerable medicinal value.[1] No thorough geological survey has been made of this area with a view to determining the origin of the zirconia. The character of the ore, however, and the formation, seem to point to pneumatolitic agencies. A careful study of the relationship of the large masses of coarsely crystalline nephelite-syenite in this area, with pronounced segregations of eudialyte, might throw some light upon this subject.

Zirkite can be roughly divided into two classes: -

First, alluvial pebbles ranging in size from one-half inch to three inches in diameter, generally carrying about 90 per cent. to 93 per cent. zirconium oxide. These pebbles, known as "favas," and having a specific gravity ranging from 4·8 to 5·2, are found along small stream beds and on the talus slopes of low ridges.

Second, zirconia ore proper, or zirkite, which ranges in shade from a light gray to a blue black, the lighter coloured material carrying a higher percentage of zirconium silicate, as evidenced by analysis, which in some cases shows a minimum of 73 per cent. zirconium oxide. The blue black ore generally carries from 80 per cent. to 85 per cent. zirconium oxide. By careful sorting, however, a uniform grade carrying about 80 per cent. is produced. Prior to the investigations of Derby and Lee, this ore was considered identical with baddeleyite. It has now been shown, however, that it is a mechanical mixture of three minerals, namely, brazilite, zircon, and a new and unnamed zirconium silicate carrying about 75 per cent. zirconium oxide. This new mineral has the same crystal form as zircon (67 per cent. ZrO_2), but is readily soluble in hydrofluoric acid while zircon is not affected, this being a characteristic differential test. The finely powdered mineral, on being treated

1 Orville A. Derby, F.G.S., "Nepheline-Rock in Brazil." From the *Quarterly Journal of the Geological Society*, August, 887.

with a weak solution of hydrofluoric acid, leaves a residue of minute, perfect, pyramidal crystals of zircon, the brazilite and new zirconium silicate going into solution. Several large outcrops of the ore occur on the extreme westerly edge of the plateau, one or two isolated boulders weighing as much as 30 tons. No extensive development work has yet been attemped, although several crosscuts have been run to determine the width of the vein, and a few shallow prospect holes to determine the depth, but seemingly, through indifference of the owners, this development work was not completed. In some of the deposits the ore occurs in the form of gravel and large pebbles embedded in a reddish clay matrix greatly resembling a boulder clay. This is mined by open cut methods. The clayey mass, on being exposed to the tropical sun and air, readily dries, and the zirconia can then be separated from the clay matrix by a coarse screen. Before shipment, it is thoroughy washed to remove the small percentage of ferruginous matter still adhering.

Most of the mines are many miles from the railroad. Horses for other than saddle purposes are practically unknown, and the ore is transported to the railroad station by ox carts carrying about one ton each. These carts are of the most primitive character, having large, solid, wooden wheels some four feet in diameter and six inches in thickness. From 4 to 8 yoke of oxen (8 to 16 oxen) are generally required for each cart, owing to the mountainous roads.

This very cursory examination of the zirconia deposits makes it unsafe to venture any conjecture as to the quantity of ore available. Suffice it to say, however, that the deposits have been traced for a distance of fifteen miles between Cascata and Caldas, and if surface indications are of any significance, are of vast extent.

Sources of Zirconium Ore.—There are only two important zirconium-bearing minerals, namely, brazilite (formerly known as baddeleyite) and zircon. The mineral brazilite, in its commercial form, is placed on the market under the name of zirkite. Zirkite, in its semi-manufactured form, carries from 75 per cent. to 85 per cent. zirconium oxide. A typical analysis, representative of several carloads of zirkite ore, made in the laboratory of Dr. C. James of Durham, New Hampshire, U.S.A., gives the following composition :—

	Per cent.
Zirconium dioxide	78·78
Ferric oxide	2·03
Titanium dioxide	0·70
Silica	17·05
Alumina	0·50
Manganese	trace
Loss on ignition	1·52

Other analyses give 71 per cent. to 80 per cent. zirconium oxide, and in the case of an almost pure brazilite analyses show as high as 93 per cent. ZrO_2.

The chief distinction between baddeleyite and brazilite rests on physical characteristics. Baddeleyite occurs in distinct crystals, whereas brazilite occurs only in fibrous, botryoidal or columnar forms. A crystallized variety of zirconium oxide, identical with baddeleyite, has been described by the late Dr. Orville Derby from the magnesite deposits of Jacupirangi, state of Sao Paulo, Brazil, and named by him Jacupirangite.

To show the variation in the character of zirkite six representative analyses are given herewith :—

		1	2	3	4	5	6
ZrO_2	...	93·18	81·75	86·57	85·93	82·00	71·88
SiO_2	...	1·94	15·49	2·50	9·35	11·38	25·31
TiO_2	...	0·69	0·50	1·43	1·84	0·36	0·63
Fe_2O_3	...	2·76	1·06	5·29	1·93	2·08	0·43
Al_2O_3	...	0·64	0·85	1·00	0·36	0·62	0·15
MnO	...	trace	trace	—	—	—	—
H_2O	...	0·47	0·63	3·32	1·56	3·35	1·56
		99·68	100·28	100·11	100·97	99·79	99·96

The other important ore of zirconia is the silicate, known mineralogically as zircon. Unlike zirkite, there are several important deposits of this type of zirconia ore in various parts of the world. The best known sources are those of Henderson County, North Carolina, U.S.A., the coastal deposits near Pablo Beach, Florida, U.S.A., the pegmatites of Southern Norway and the coastal deposits of Brazil—particularly the latter. In the case of the Florida and Brazil deposits the zircon is secured as a by-product in the electro-magnetic concentration of monazite sand.

Zircon sand consists of minute, glassy crystals, and has very much the appearance of a fine, white sea sand. There has been practically no important production of zircon in the United States during the last five years. A theoretically pure zircon only carries 67 per cent. zirconium oxide, and the average zircon sand carries about 64 per cent. ZrO_2, whereas even the lower grades of zirkite carry a minimum of 70 per cent. ZrO_2. This low oxide content, coupled with the fact that zircon is not so amenable to chemical treatment as zirkite, makes it very doubtful whether there will be an extensive demand for zircon, at least for present purposes.

Application as a Refractory.—The remarkable heat-resisting qualities of zirkite at once commend it as a refractory of the first order. Its high melting point, low coefficient of expansion and low thermal conductivity, make it an ideal lining

for electric furnaces of either the arc or resistance type. The pure oxide, owing to the comparatively high cost of extraction and purification, is too costly at the present time for industrial uses on a large scale. Careful tests have shown, however, that zirkite is eminently fitted for such work.

To compete with the various other high grade refractory bodies now used industrially, zirkite must necessarily possess certain refractory qualities lacking in its rivals, such, as for example, a higher melting point or greater resistance to chemical agencies. In other words, the initial cost of a zirkite lining, which is rather high as compared with, for example, magnesite brick, is more than offset by its low thermal conductivity and low coefficient of expansion.

There are many difficulties attending the manufacture of zirkite brick. Zirkite itself has little or no plasticity, and the initial experiments made by the author and several experienced firebrick manufacturers, show that the selection of the proper binder governs the melting point and fire shrinkage of zirkite brick. The high percentages of silica and iron oxide also play an important part in the behaviour of the material when subjected to high temperatures. It will be noted from the foregoing analyses that the only two oxides present which would be likely to cause a lowering of the melting point are silica and ferric oxide. The small percentage of titanium oxide present may or may not exert a fluxing action at high temperatures.

In preliminary work, small briquettes measuring 36 × 20 × 5 mm. were made from the following mixtures. These were thoroughly dried and burnt at a temperature of approximately 1,427° C., with the following results: —

Linear Shrinkage.

	Per cent.
No. 1	9
No. 2	9
No. 3	9
No. 4	12
No. 5	3

No. 1. Pure zirconium oxide (99 per cent. ZrO_2).
No. 2. Water-ground zirkite (84 per cent. ZrO_2).
No. 3. Semi-purified zirkite (95 per cent. ZrO_2).
No. 4. 93 grams of No. 3 and 7 grams Dry Branch kaolin.
No. 5 60 grams zirkite, 80-mesh, and 40 grams zirkite cement.

Briquette No. 1, made from pure zirconium oxide analysing about 99 per cent. ZrO_2, yielded a sticky mass on mixing with water and was quite soft after drying. After burning, No. 1 was still in a soft condition and could be readily scratched with the nail.

Briquette No. 2 consisted of zirkite carrying about 84 per cent. ZrO_2. As indicated, this material was wet-ground in a ball mill and thus reduced to an extremely fine state of subdivision. It was readily moulded into shape. Firing rendered the material extremely dense and of a flint-like hardness. Several briquettes were heated to redness and one end plunged into a beaker of water. This quenching test apparently left the material unaffected, as no cracks were developed.

Briquette No. 3 was made from 95 per cent. zirconium oxide. This 95 per cent. product was prepared on a small scale from zirkite. Much of the silica and nearly all of the iron were removed by this refining, which yielded a light gray product, After firing, the briquettes presented a very dense structure and were extremely hard.

Briquette No. 4 shows the bad effect of even a small percentage of a very refractory china clay. Dry Branch kaolin is a pure white, washed clay, having a fusing point above 1,790° C.

Briquette No. 5 was made from a mixture of 60 grams coarse zirkite (material passing through an 80-mesh screen) and 40 grams water-ground zirkite, or material similar to No. 2. It will be noted that the shrinkage in this case was extremely low. The briquette, after firing, presented a rather coarse, porous texture, but possessed considerable tensile strength.

Whether these shrinkage figures would be much greater at higher temperatures it is difficult to say.

Tests made by G. T. Stowe at the Ohio State University, on using zirkite ground to 100-mesh and moulded into cones, showed no fusion at cone 35 (1,830° C.). The material burnt with little warpage or shrinkage and showed only slight vitrification. With a view to finding a suitable bonding material, he used a mixture consisting of 95 per cent. zirkite, 100-mesh, and 5 per cent. of a highly siliceous fireclay. This mixture was made into cones and subjected to a temperature of about cone 32 (1,770° C.). Little warpage or shrinkage was noted and only slight vitrification. A mixture of 98 per cent. zirkite and 2 per cent. slacked lime proved that the addition of this latter oxide lowered the melting point markedly.

A series of tests made by Mr. R. C. Gosrow on zirkite gave the following interesting results. The tests were made in the form of small briquettes measuring $1\frac{1}{4} \times 1\frac{1}{4} \times 4$ in. in a steel mould. The material was rammed in place with considerable pressure. Five such tests were made as follows:

(1) Zirkite powder, bonded by 26·5 deg. Bé $MgCl_2$ solution (concentrated from salt bittern). Mixed to consistency of a stiff mud and rammed. Dried 5 days—100° C. Dried 8 hours —150° C. Heated gradually to bright red and exposed to

temperature of 1,600° C. in an electric arc furnace for two hours. The sample showed no fusion; corners sharp and hard; scratch glass; shrinkage slight; FeO and Fe adhere in molten condition; FeO showed corrosion; very dense; difficult to crack with bricklayer's hammer.

(2) Zirkite powder, 50 per cent.; dead-burnt magnesia (electrically dead-burnt), 50 per cent.; bonded by 26·5° Bé $MgCl_2$ solution and mixed to hard, stiff mud and rammed. Dried same as 1. Heated to same temperature and for same time as No. 1. Fused to spongy mass, dark colour. The fusion was evidently caused by iron oxide and silica.

(3) Zirkite powder, 10 per cent.; dead-burnt magnesia, 88 per cent.; 26·5° Bé $MgCl_2$ solution, 2 per cent. Mixed to stiff mud and rammed. Dried and heated same as for No. 1. Hard, dense, compact brick; sharp, hard corners; positively no fusion; showed no corrosion by FeO; light brown colour.

(4) Zirkite powder; bonded by 30° Bé Na_2SiO_3 solution to form stiff mud and rammed. Dried and heated same as No. 1. No fusion; extremely hard, dense; interior appeared denser than exterior; slight crack in interior, probably due to moisture.

(5) Zirkite powder; bonded by small amount of water in form of vapour, mixed to stiff mud and rammed. Dried and heated same as for No. 1. Compares to properties of No. 1. Showed same FeO corrosion.

With the exception of No. 2, which fused, the samples showed :—

(1) General corrosion by FeO in spots.
(2) Slight shrinkage.
(3) Withstood temperature changes from 500° C. to 1,600° C. without any cracking or spalling.
(4) No contortion or deformation at high temperatures.
(5) Precaution necessary in choosing suitable binder, and also care to be used in mixing other refractory substances containing impurities as FeO, SiO_2, etc.
(6) Zirkite can be used equally with magnesia, and with less cost for linings, etc.

The results secured by Mr. Gosrow under test No. 3 appeared promising enough to warrant further investigation along this line. Preliminary tests indicate that magnesium chloride would be objectionable on a commercial scale. Hence, another binder was sought and ultimately found in water-ground zirkite. It was further considered that the dead-burnt magnesia (electrically dead-burnt) might be successfully replaced by ordinary calcined magnesite, such as is used for

magnesite cement in flooring. This product carries about 93 per cent. magnesium oxide, with a small percentage of carbon dioxide, calcium oxide and silica.

The following formulas were used[1] in the making of several small briquettes, which were carefully dried and burnt at a temperature of approximately 1,427° C. in a small muffle furnace :—

FORMULA 3A.

45 grams zirkite (ground to pass through 80-mesh screen).
45 grams magnesium oxide (calcined).
10 grams water-ground zirkite.

The briquettes after burning were of a brownish-yellow cast, with a rather loose texture, but quite resistant to abrasion and of a fair tensile strength. The fire shrinkage at the above temperature was approximately 8 per cent. linear measurement. One of the briquettes at a white heat was dropped in a beaker of water, but no cracks were developed and the material was apparently as solid as before quenching.

FORMULA 3B.

72 grams zirkite (ground to pass through 80-mesh screen).
18 grams magnesium oxide (calcined).
10 grams water-ground zirkite.

Briquettes made from this formula had very much the appearance of those produced by formula 3A. The fire shrinkage was approximately the same. The specific gravity was of course higher, owing to the greater percentage of zirkite present. The results of these tests were considered rather encouraging, and further investigations are now under way. The strong objection to the use of the magnesium oxide, particularly the calcined product, is the fact that it has an extremely high shrinkage. This of course is not true of the costly electrically shrunk magnesium oxide, but the tendency would naturally be toward the use of the cheaper calcined oxide.

As will be noted under fire shrinkage, briquette No. 4, mixed with a 10 per cent. bond of refractory clay, showed extremely high shrinkage. It was decided, however, to manufacture a few standard-size firebricks, using a 5 per cent. bond of Warrior Ridge clay, as mentioned above. The zirkite was ground to pass through an 80-mesh screen and thoroughly mixed in a dry pan with 5 per cent. of the aforementioned clay. The mass was slightly moistened and formed into bricks in the same manner as is pursued in the manufacture of silica or chrome bricks. After thoroughly drying, these bricks were

[1] By J. R. Adams under author's supervision.

burnt in a silica brick kiln, at an estimated temperature of at least 1,649° C.

No figures were secured as to the fire shrinkage, but even this small percentage of clay caused the bricks to soften at a temperature well below the fusion point of zirkite. The standard bricks made from the material weighed on an average 13 lbs. each.

To determine the behaviour of the material when in contact with carbon at high temperatures,[1] a brick was made a part of one side of the trough of a granular carbon resistance furnace, the rest of the trough being made of magnesite brick, all being backed up by firebrick. A pyrometer tube was put in so as to give the temperature of the surface of the brick, next the carbon resistor, and temperatures read with a Wanner pyrometer. In about one half-hour after starting, the temperature was 1,800° C. ± 25° and it was held between 1,750° and 1,850° C., averaging 1,800° C. ± 25° for 1½ hours. The furnace was then torn apart. The zirkite brick was just nicely red on the back (2½ in. from the resistor), while the magnesite bricks were much redder. From this and from the temperature of the firebrick backing when felt from time to time, it is plain that zirkite has a considerably lower thermal conductivity than magnesite, and quite probably the lowest of any available material that will stand 1,800° C.

The brick, when put in place, had a slight crack, and this increased a little on heating, but not very badly. Magnesite bricks on both sides of it were badly cracked. A slight shrinkage was noted on the hot face, and the surface of the zirkite brick was slightly pitted and spongy. The spongy layer was only about ⅛ in. thick. The magnesite bricks were considerably more acted upon by the carbon than the zirkite bricks, their surfaces being eaten away uniformly over ⅛ in. Hence, as regards the action of carbon on the hot brick, the zirkite brick appears superior to magnesite, but inferior to carborundum.

The zirkite brick was not supporting any weight, and only the inner face reached 1,800° C. The brick had not really fused nor flowed of its own weight, *i.e.*, it might not have failed under a "cone test" at 1,800° C. Yet when the brick was picked up with tongs, they sank into the hot face, under gentle pressure, to a depth of ½ in.

The face of the brick was very plastic, and though it had not really fused nor flowed out of shape, the fact that the brick as a whole kept its shape was due to the stiffening effect of

1 The following data was contributed by an experienced investigator, who requests that his name be withheld.

the comparatively cold back of the brick. If the whole brick has reached 1,800° C., and had been under any pressure, as in a wall with other courses of bricks resting on it, it would certainly have been pressed out of shape.

It therefore appears that 1,800° C. is the upper limit at which this brick (zirkite bonded with Warrior Ridge clay) could be safely used. It is of course quite possible that a brick bonded with water-ground zirkite and free from clay bond might be stiffer and stand up at a higher temperature.

Therefore, while this particular brick is not as refractory under furnace conditions as the reported melting point of zirkite would lead one to expect, it is still refractory enough to be classed among the half-dozen highest refractories; while not entirely free from shrinking and cracking, its behaviour in this respect is far better than magnesite, although not as good as carborundum. Its heat conductivity is apparently less than any other of our high refractories. Its behaviour in contact with carbon, while not perfect, is not so bad but that it can probably be controlled.

A satisfactory commercial process has now been perfected for the manufacture of zirkite brick. All standard shapes are now being made and are finding wide application in the United States for lining electric furnaces. Essentially, the American method of manufacturing zirkite brick consists in first passing the ore through a crusher and grinding to about 60-mesh in a dry pan, removing all particles running finer than 100-mesh by passing over inclined screens and bonding the resultant product with zirkite cement. About 50 per cent. of 60-mesh zirkite and 50 per cent. of zirkite cement constitute the refractory mass. This is made into a stiff mud with water and moulded in the same fashion as silica brick. "Green" zirkite brick have to be dried very slowly, as otherwise they develop air cracks. Furthermore, great care should be exercised in setting them, as they are very brittle in the unburnt state. The percentage of loss is rather high, but the warpage and cracked bats can be used over again after regrinding in the dry pan.

Unfortunately, war conditions prevent the enumeration of the many uses to which zirkite is now being put as a refractory body. It is to be hoped that such information will not be lost, and that following the war there will still be a greater development in the uses of this new refractory.

Ferrozirconium.—Various unauthenticated reports have been circulated in the United States as to the remarkable properties of German armour-plate, samples of which are said to have been analysed and found to contain zirconium. It has

already been noted that Krupp's, of Essen, were prior to the war investigating zirconium, and it is interesting to note that the Brazilian Government reports show that in 1913 there was exported from that country 1,119 tons of zirconium ore. As there was no important consumption of the ore at that time in either the United States or England, it is natural to assume that nearly all of this tonnage went to Germany.

It has been known for some time and patents have been granted on the application of ferrozirconium as a scavenger for removing nitrogen and oxides from steel. One of the most recent alloys of zirconium placed on the market, consists essentially of between 40 per cent. and 90 per cent. zirconium, with the residue mainly iron or an iron group metal. Small percentages of titanium and aluminium are also introduced. This series of alloys is covered by U.S. Patent No. 1,151,160. It is claimed that the alloy is not subject to oxidation, is highly resistant to chemical reagents and is readily malleable. It is suggested that one of the alloys in this series may find important application in the manufacture of drawn filaments for incandescent lamps. Such filaments are claimed to have the property of selective radiation; in other words, emit more light than corresponds to the temperature at which they are heated by the electric current. This implies a considerably lower wattage per candle power than is now required by the average metal filament lamp. A typical analysis of some of the alloys produced under the above patent shows: zirconium 65 per cent., iron 26 per cent., titanium 0·12 per cent., and aluminium 7·7 per cent. The production of the alloys is accomplished either by reduction with finely divided aluminium together with the mixed oxides of iron, titanium, etc., or whatever metals it is desired to introduce into the alloy; or they can be produced by heating the mixed oxides in a graphite crucible in an electric furnace, using either zircon or zirkite as a source of zirconium.

Metallic Zirconium.—This has been produced in small quantities by Dr. C. James, of New Hampshire College. It is in the form of a grayish black, amorphous powder, which gives a powerful evolution of hydrogen when treated with hydrofluoric acid. When shaken near a flame the metal produces brilliant sparks, and small quantities can be readily ignited with a match. There are two other forms of metallic zirconium, namely, the crystalline and the graphitic types. The crystalline form has a density of 6·4 and a melting point of 1,500° C.

Zirkite Ware.—The investigations of Dr. Charles Morris Johnson during the past few years have resulted in the manufacture of laboratory ware from zirkite mixed with other

refractory bodies. Zirkite filtering crucibles, muffles, combustion tubes, combustion boats, pyrometer tubes and Kipp generators with replaceable units, are now on the market at prices comparing favourably with like articles of chemical porcelain or fused silica. Zirkite combustion tubes have been reported running in steel testing laboratories on carbon determinations for as long a period as three months, being used constantly day and night. Owing to the composition of these tubes they are not attacked by basic substances, do not devitrify, and are gas-tight up to temperatures of 1,000° C.

Summary of the Commercial Uses of Zirconium:—

(*A*) 1. The metal alloyed with iron is now finding application in the steel industry as a hardening agent.
2. As a scavenger for removing nitrogen and oxides from steel.
3. In the manufacture of drawn filaments for incandescent lamps.
4. Alloyed with nickel for the production of high-speed cutting tools.

(*B*) 1. The carbide is employed as a filament for incandescent lamps.
2. As an abrasive.

(*C*) 1. The oxide is employed as a refractory body either in its pure form or in the semi-purified state known as zirkite.
2. In the manufacture of zirkite bricks.
3. In the manufacture of small highly refractory utensils for laboratory purposes.
4. Combined with yttrium earth oxides for the manufacture of Nernst glowers.
5. As a substitute for calcium oxide in "lime" light cylinders and in the manufacture of pencils for the Blériot automobile headlight.
6. As an acid-proof enamel.
7. As a substitute for bismuth salts in making X-ray photographs.
8. As an addition to fused silica ware for the prevention of devitrification.

(*D*) 1. The nitrate has been employed as a food preservative.
2. In the "lighting" fluids used in the manufacture of incandescent mantles.

(*E*) 1. The basic acetate is employed for weighting silks.

XIII.—Ovens and Kilns with a High Thermal Efficiency.

By A. BIGOT, Dr. es-Sciences.

1.—Industrial Laboratory Kilns.

IN 1892, at the outset of my studies on stonewares and porcelains, I needed a laboratory kiln capable of rapidly attaining the temperature 1,400° C. in an oxidizing, reducing or neutral atmosphere; this object was easily attained by the addition of a sheet-iron recuperator to the Perrot kiln. (See Fig. 1.)

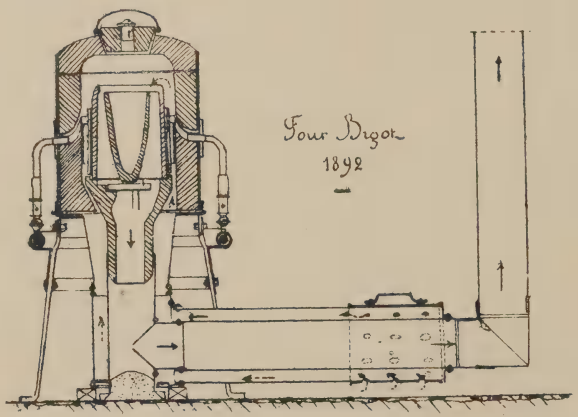


Fig. 1.

The tube T for the escape of the combustion gases is surrounded for a length of about 2·5 metres (100 inches) by a tube T' of greater diameter; this tube T' is pierced at its extremity by openings O, the dimensions of which can be easily regulated. When the kiln is kindled, the combustion gas draws in air from between the tubes T and T'; it makes a draught by the openings O, and the secondary air, which passes between the two tubes, arrives in the kiln hot and contributes towards the combustion of the gases.

In the Perrot kiln a mean temperature of 1,200° was attained; with this modification it became possible to reach

1,400° in the same time, that is to say, to raise the temperature of the interior of the Perrot kiln by 200° without increasing the quantity of gas burned.

In 1915 I again took up the study of this kiln in order to obtain higher temperatures. I surrounded the sheet-iron recuperator with insulating materials, and, after this improvement, I obtained at the first firing a temperature of 1,750° C. at the end of five hours, burning illuminating gas of inferior quality under a pressure of 40 mm. (about 1·6 inches) of water, and without air blast. After a first operation the refractories lining the interior of the kiln were half melted; at the end of the second firing the iron sheets of the recuperator were oxidized and perforated. To remedy these inconveniences I replaced the aluminosilicate parts of the interior of the kiln by more refractory materials, and constructed the recuperator with suitable refractories. (See Fig. 2a and 2b.)

The kiln (Fig. 1) is of small internal capacity; only small objects can be heated in it, and the very hot zone is rather restricted. It was interesting to construct a laboratory kiln permitting regular heating of more important pieces and maintaining them for several hours if necessary at a fixed temperature.

When requested by the Minister of Munitions and War Manufactures to instal recuperative kilns of my pattern at the testing laboratory of the Conservatoire National des Arts et Métiers, I succeeded in meeting the requirements expressed above, with the co-operation of Captain V. Bodin, head of the third section of materials at the testing laboratory. This kiln is rectangular; the recuperator is the same as that of my 1915 kiln; the body of the kiln is lined with insulating bricks, and the upper part is covered again with a layer of incombustible insulating powder. The external structure of the kiln is strengthened with concrete, but it could be made of sheet-iron. Internally the kiln has a working capacity of nearly two cubic feet; it could be reduced or increased. (Fig. 2 a and 2b.)

From the first firing the temperature of the kiln reached 1,750° at the end of 5½ hours. Above this temperature the refractory material of the interior of the kiln began to be deformed, and 1,750 C. constituted the practical limit which could be attained with the actual refractory materials. The curve below (Fig. 3) indicates the rise of temperature of the kiln when fired, and on examining this curve it is easy to see that it was possible to reach a higher temperature. In this operation silica bricks and corindite bricks were heated; the former melted or were largely deformed. To attain this temperature the expenditure of illuminating gas, of inferior quality, was on the average

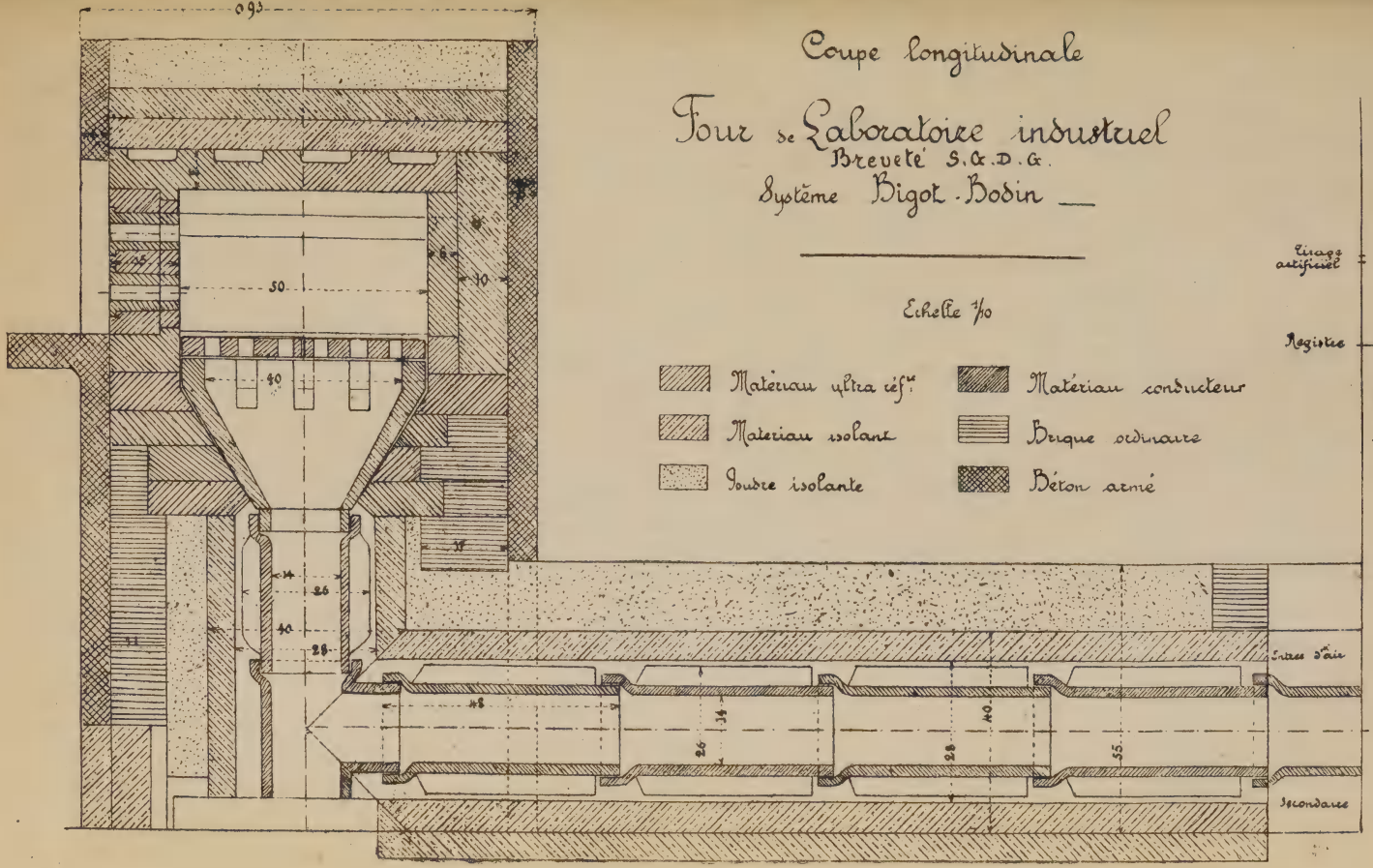

Coupe longitudinale
Four de Laboratoire industriel
Breveté S.G.D.G.
Système Bigot-Bodin
Echelle 1/10
Matériau ultra réfr.
Matériau isolant
Poudre isolante
Matériau conducteur
Brique ordinaire
Béton armé
Tirage artificiel
Registre
Cheminée
Entrée d'air
Secondaire
093
50
40
10
26
28
34
55

Fig. 2a.

10 cubic metres per hour, under a pressure of 40 mm. of water and without air-blast. Thus, by partial recuperation of the lost heat, and by the employment of insulating materials, I

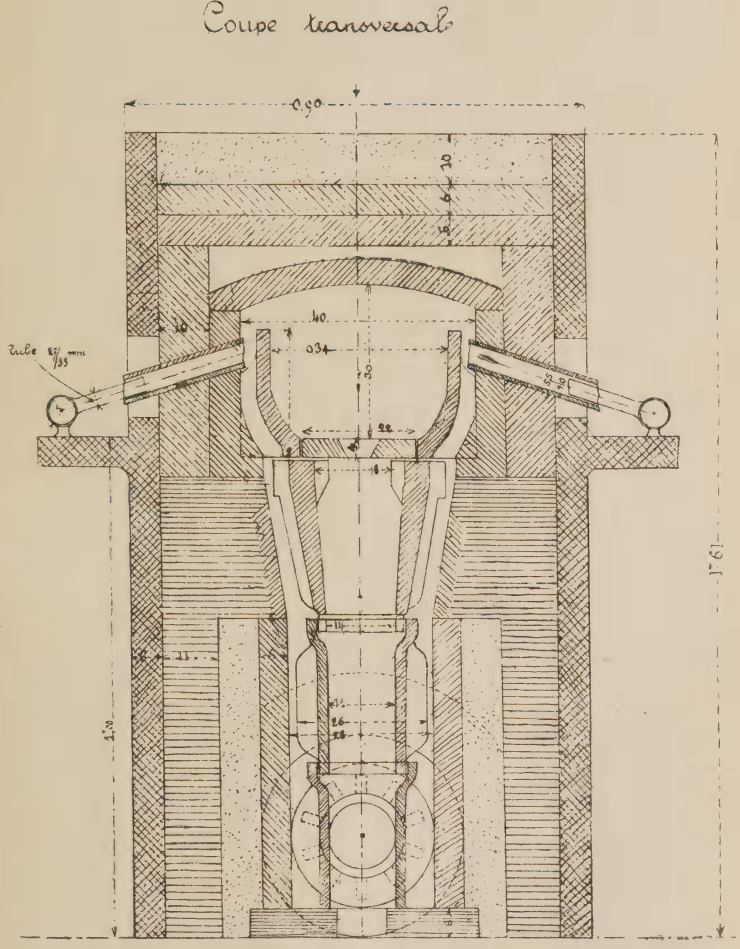


Fig. 2b.

transformed the Perrot kiln, where a temperature of 1,200° was attained, into a kiln where 1,750° was attained, a temperature increase of 550° without increasing the consumption of fuel.

2.—*Industrial Kilns.*

(1) *Intermittent Kilns.*—The preceding kiln is an intermittent kiln of small capacity; it is easy to adapt to industrial intermittent kilns the same systems of recuperation and

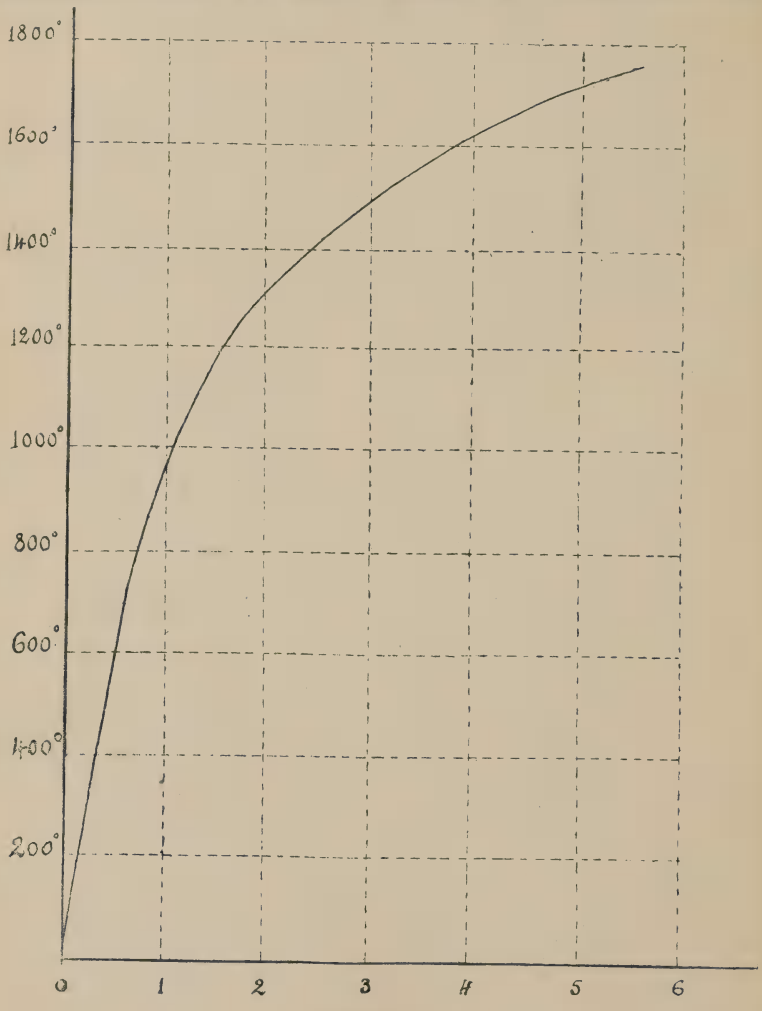


Fig. 3.

insulation, whatever be the mode of firing; high temperatures will be obtainable in these kilns, which is practically impossible with the patterns in actual use. I have applied these principles to kilns with movable bottoms and with fixed hearths.

(2) *Kilns with Movable Bottoms.*—These kilns, termed *tunnel kilns*, offer advantages which I indicated by as exact calculations as possible in the lecture which I delivered at Stoke in 1915 (TRANS., **14**, 115, 1915). My attention had then been called to the loss of heat which is produced in tunnel kilns by the wagons, the sides and the ground, and I indicated the effect of the judicious employment of insulating materials.

Insulating materials.—Since that period I have completed my studies of these materials. A certain number of minerals occur in light powder which can, if necessary, be agglomerated in the form of bricks or special pieces, of small apparent density. These minerals contain a notable proportion of air shut up in their pores, which makes them bad conductors of heat; among these minerals may be named asbestos, light magnesia, infusorial earth, etc. A light powder of apparent density 0·2 can be agglomerated in the form of brick with sufficient crushing strength, of apparent density 0·5.

On comparing the conductivity of the refractory brick at ordinary temperature (conductivity 100 times less than that of gold) with the conductivity of the light powder of density 0·2, and that of the brick of density 0·5, the powder is found to be *ten times less conducting*, and the insulating brick *six times less conducting*, than the refractory brick. It is known that the coefficient of conductivity of refractory products increases rapidly with rise of temperature, and the same is the case with insulating products. At 800° C. the conductivity of the insulating brick became six times greater, being then the same as the conductivity of the refractory brick at ordinary temperature. At 800° C. the conductivity of the insulating powder equally became six times greater, but it is still inferior to that of the refractory brick at ordinary temperature. Above 800° C., in proportion as the temperature is raised, the insulating powders tend to agglomerate, their volume diminishes, part of the air they contain disappears, and they have become more conducting. The agglomerates shrink, losing little by little the greater part of the confined air; they tend to become as compact as the other ceramic materials and their conductivity increases. According to my experiments the practical limit of temperature to which insulators can be submitted does not exceed 1,000° C.; they ought then never to be employed for the internal lining of kilns.

The mean specific heat of refractory products and of insulating products is about 0·25 up to 1,000° C.; the apparent density of ordinary refractory products is about 1·80, that of insulators above described is 0·50 for the blocks and 0·20 for the powder. It is easy to calculate the quantities of heat

absorbed by equal volumes of these various materials; it is sufficient to multiply their weight by their specific heat and by the number of degrees Centigrade by which their temperature has been raised. The quantity of heat absorbed will be proportional to the apparent density of these products; the refractory product of density 1·8 absorbs 3·6 times more calories than the insulating brick of density 0·5; it absorbs 9 times more calories than the powder of density 0·2.

Consider a kiln maintained internally at 1,000° C., and of which the walls (0·69 m. or about 27 in. thick) are constructed of bricks 0·23 m. (9 inches) long; when equilibrium is reached the temperature of the external part of the brick will be say 100° C.; the face of the brick at 100° C. loses by radiation into the atmosphere a certain number of calories which can be easily determined. The heat received by the internal wall of the kiln can be divided into three terms: A. The quantity of heat necessary to raise the temperature of the walls, arches and foundations of the kiln till equilibrium is reached. B. The quantity of heat which radiates into the atmosphere owing to the difference of temperature between that atmosphere and the external walls of the kiln. To this quantity of heat lost by the air must be added the quantity of heat lost in the ground by conductivity. C. The quantity of heat which the internal wall radiates into the interior of the kiln.

Retaining in the kiln the range of internal refractory bricks of 0·23 m. (9 in.) thickness, I replace the two other ranges of bricks forming a thickness of 0·46 m. (18 in.) by an insulating brick which is six times less conducting; this brick then should be one-sixth as thick, 0·0766 m. (3 in.), in order to preserve in the wall as a whole the same conductivity. The quantity of heat absorbed by this new wall composed of refractory bricks and insulating bricks will be a little more than a third of the heat absorbed by the wall of 0·69 m. thickness. In place of this insulating brick of 0·0766 m. thickness, I put round the kiln a quantity of powder in such a manner as to preserve on the whole the same conductivity; this layer of powder will have a thickness of 0·046 m. (about 1·8 in.). The quantity of heat absorbed by this new wall will be still smaller than in the preceding case.

The walls of the kiln constructed with a range of bricks 0·23 m. thick surrounded by 0·046 m. of insulating powder fulfil the same purpose as the brick wall 0·69 thick, but it absorbs about one-third as many calories; the loss by radiation into the air and by conductivity into the ground is the same in the two cases; in order to remedy this loss of heat by radiation into the air and conductivity into the ground, and to make it

almost nothing, it is sufficient to increase the thickness of the insulating light bricks or powders which then form a kind of eider-down around the kiln; the thickness of these insulators should be 0·10 m. to 0·50 (about 4 to 20 inches), according to the internal temperature of the kiln, in order to obtain good insulation. The heat *B*, which will no longer radiate into the air and that which will no longer pass away into the ground, will return into the interior of the furnace as radiant heat, which will promote a rise of temperature. The use of the insulating material thus effects a double economy in calories.

Before undertaking a complete trial of the process of insulation on a whole kiln I made a partial application on the arch of an intermittent kiln. The arch of this kiln had been constructed with refractory bricks 0·23 m. thick, and this arch, in a first experiment, had been re-covered by a layer of 0·25 m. of rather coarse sand. The kiln being kindled, a temperature of 1,320° was obtained at the end of 78 hours. In a second trial, carried out under the same conditions, the sand was replaced by a layer (0·15 m. or 6 in.) of insulating powder; a temperature of 1,320° was reached at the end of 28 hours, firing with an expenditure of fuel half that of the preceding operation; after 58 hours heating the temperature reached was 1,465°. The curve below (Fig. 4) traces the course of the trial. The numbers on the vertical lines indicate the temperatures attained in degrees Centigrade; those on the horizontal lines represent the hours from the commencement of the operation. The curve *A* is that of the first trial, the curve *B* that of the second.

Refractory Materials.—The wagons hitherto adopted in tunnel kilns move on wheels or on metal rollers, which it is necessary to cool in order to avoid corrosion. The wagons are cumbersome, they involve an increase in the size of the tunnel and bring about important heat losses. In order to remedy these inconveniences as far as possible I employed the following method. The material to be fired is supported on plates which move by means of a system of balls rolling on a fixed floor, the whole being made of special refractory material having three chief qualities: (1) Resistance to wear and tear at both high and low temperatures; (2) crushing strength at various temperatures; (3) ability to withstand changes of temperature. If these three qualities are not combined the practical employment of these wagons is impossible. After a series of studies on resistances to wear and tear or ability to stand changes of temperature, and crushing strength up to 1,500°, undertaken with different materials, I succeeded in solving the problem. It is known from the experiments of

Captain V. Bodin, that a great number of refractory products present a maximum crushing strength between 1,000° and 1,200°, and that above this temperature it decreases very rapidly. Certain refractory products attain at about 1,100° a crushing strength of 1,700 kilogs. per sq. cm.

The materials which I use for the rolling belong to the category of those which offer this high resistance; they can be heated to 1,100° without suffering deformation. In my tunnel kilns intended to reach about 1,100° the rolling system

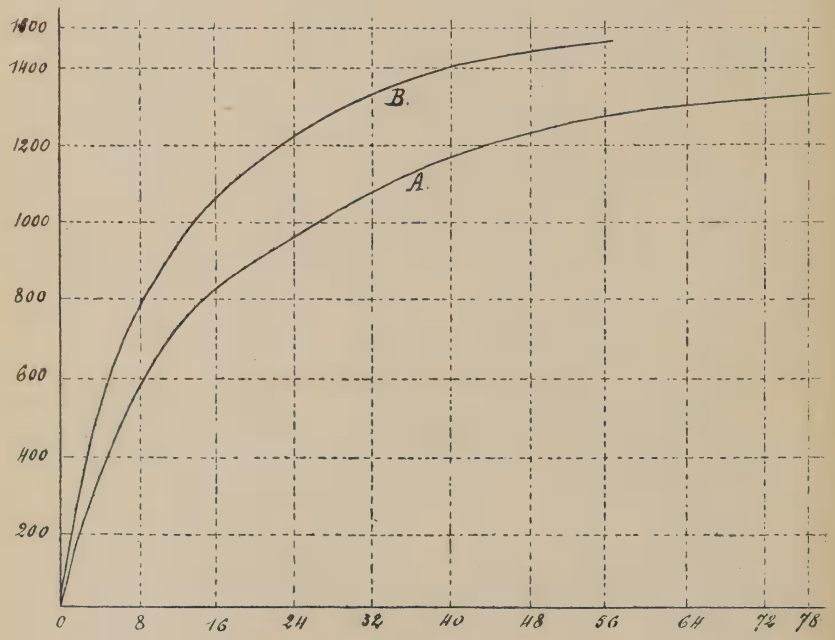


Fig. 4.

is carried to the same temperature as the goods which it supports, and its volume is reduced to the minimum; I have given to these kilns, which will be described briefly further on, the name of *Tube-kilns*.

For temperatures above 1,100°, prudence requires that the rolling system be not submitted to a higher temperature; in a kiln heating to 1,550°, the balls are about a foot below the goods; I have called these *Tunnel-kilns*.

In these kilns, completely surrounded by insulators, very little is lost either by the air or into the ground, as I demonstrated above; since everything in them maintains a high

thermal efficiency their dimensions can be reduced and they can be adapted to the firing of small lots, whereas the tunnel kilns hitherto employed can only be economically used for the firing of large quantities. The temperatures obtained in my tunnel kilns are comparable to those which I reached in my industrial laboratory kiln.

Description of the Kiln with Movable Bottom.—Tube kilns and tunnel kilns require five principal parts: A. The rigid covering. B. The bottom of the kiln. C. The tube or tunnel. D. The movable parts and the rolling way. E. The insulating covering.

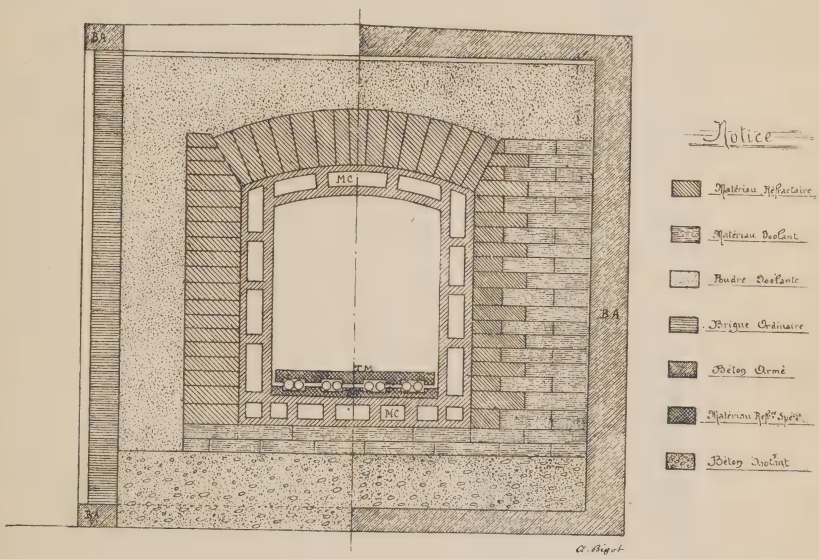


Fig. 5.

A. *Rigid Covering.*—This covering consists of a body of ferro-concrete represented by the sections B A in Figs. 5 and 6, and by the photograph (Fig. 7). Vertical parallel posts are supported by horizontal beams at their base and apex, these beams being parallel and perpendicular to the axis of the kiln; the two vertical faces, between the posts, are filled up with ordinary bricks, laid flat on a width of 0·11 m. with cement or lime mortar. A long, rigid but light chamber is thus obtained.

B. *Bottom of the Kiln.*—The lower part of the chamber is filled up to a suitable height with insulating concrete resting on the ground; on this concrete one or two ranges of insulating

bricks are laid out, placed flat with insulating grout; the surface of these bricks should be as plane as possible, and it is on this surface that the other three parts of the kiln are established.

C. *Tube and Tunnel.*—These are composed of two vertical walls of bricks 0·23 m. in thickness, terminated above by an arch of bricks of the same dimension or by large curved slabs forming a roof. The material and the form of the bricks or slabs vary according to the temperature to be obtained in the kilns.

The interior of the tube-kiln is provided from end to end with hollow refractory materials, M.C., which are as highly

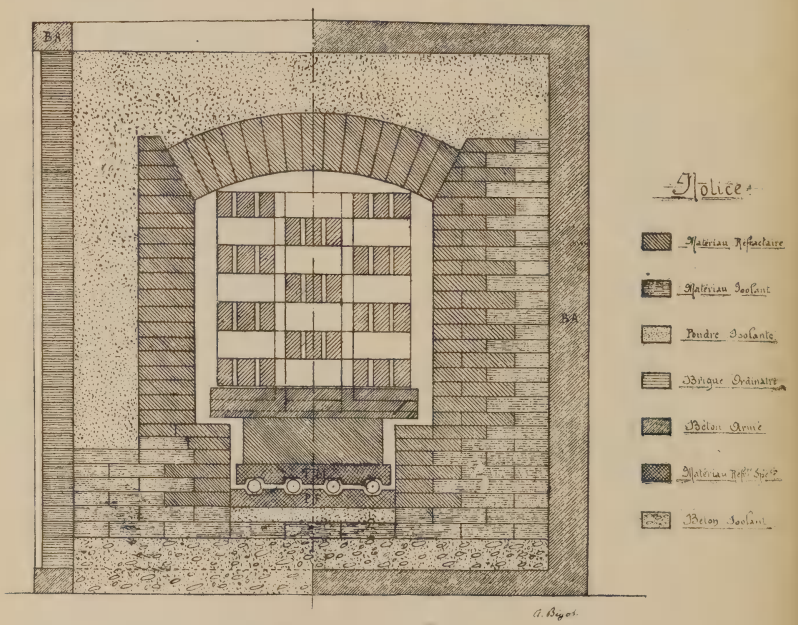


Fig. 6.

conducting as possible; the introduction of the air, the combustion, and the ejection of the gases occur in these passages.

In order to ensure rigidity of the tube or tunnel it is necessary to place opposite each vertical post of ferro-concrete a wall 0·11 m. thick of insulating bricks, which starts from the external wall of the tube or tunnel and rests against the vertical posts of ferro-concrete (Figs. 5 and 6).

D. *Movable Part and Rolling Way.*—The lower part of the tube and tunnel is provided with special refractory slabs

made of the same material as the balls and the movable plates, and on these lie the movable balls. The dimensions and shapes of these slabs are variable; they are represented by the letters P F in Figs. 5 and 6, the letters T M representing the movable part of the wagon. In the tunnel kiln the movable wagon is provided with a refractory chamber covered with plates which carry the materials to be fired (Fig. 6).

Tube Kilns.—These are muffle kilns which can be heated up to 1,100° in an atmosphere which can be made at will oxidizing, reducing, or neutral. These kilns are likely to be of interest in a great number of industries: (1) Reheating of metals, enamelling of metals. (2) Annealing of glass, enamelling of glass. (3) Fine earthenware, decoration of ceramic products. (4) Crucibles and other materials made of plumbago or graphite. (5) Various chemical products, etc.

The temperature of these kilns is limited because of the low crushing strength above 1,200° C. of the refractory materials actually used; but studies in progress suggest that in the near future refractory products with a resistance at above 1,500° C. of more than 600 kilogs. per sq. cm. of surface will be manufactured. The field of application of tube kilns will then become much greater.

Tunnel Kilns.—With the refractory materials actually at disposal, tunnel kilns can be heated practically up to 1,100°. The arrangement drawn in Fig. 6 is that of a kiln directly heated; the combustion gases traverse the ware. This tunnel kiln can be heated, like a muffle, both by radiation of heat on the two sides and by the arch.

My first tunnel kiln with direct heating was constructed at Paris two years ago in one of the factories of M. Guérineau, President of the Syndicate of Ceramic Products of France. This kiln, which was intended to fire, at high temperatures, about 3 tons of special refractory bricks, has very small dimensions and yet very high thermal efficiency. It has served at the same time as an experimental furnace for firing very varied products.

For several practical reasons the fuel adopted was illuminating gas of reduced calorific power, about 8,000 calories per kilog., similar to the calorific power of coals of ordinary quality. This kiln is heated with simple Bunsen burners, like a Perrot kiln; but the greater part of the air which serves for combustion passes over the fired and hot goods before mixing with the gas, which causes a considerable rise of temperature. Thanks to a special arrangement, the fired products can be cooled pretty rapidly and the greater portion of the heat which they contain can be recovered again after the passage of the air necessary

for combustion; it is known, in fact, from calculations established in my lecture at Stoke in 1915 that the air necessary for combustion recovers from the fired goods only a third of the heat which they have absorbed. This cooling arrangement allows shortening, by half, the length of the tunnel kiln between the fireplaces and the discharging place for the wagons. Fig. 7 represents the photograph of half a tunnel kiln. Fig. 8 represents that of a wagon loaded with chromite bricks, at the discharging end of the tunnel after firing at 1,450°.

But this kiln allows only a length of 15 metres between the fireplaces and the exit flues for the gases; this length is

Fig. 7.

quite insufficient, and, from measurements of the temperature of the gases at the outlet, 20 per cent. of the heat escapes in the flues. If the length of this part of the kiln were doubled and carried to 30 metres the loss of heat by the chimney would fall to 10 per cent., so that this tunnel kiln of normal construction should have a length of about 50 metres, the same as for firing at a high temperature. The heat which escapes through the flues and the heat recovered from the ware in cooling can be utilised to dry the products before firing them.

Consumption of Fuel.—From the results which I obtained in 1915 for kilns heated to 1,000°, from new results which have

been supplied to me by manufacturers since then, and with the official report of daily consumption of my tunnel kiln, the following numbers can be considered as accurate. An intermittent kiln heated to about 1,000° utilises 20 per cent. of the calories of the fireplace; heated to 1,400° it utilises 10 per cent. of the calories of the fireplace. An ordinary Hofmann kiln heated at 1,000° utilises 40 per cent. of the calories of the fuel. A Hofmann kiln heated by the gas producer to 1,250° utilises also 40 per cent. of the calories of the fuel. A Hofmann kiln heated by the gas producer to 1,250° utilises also 40 per cent. of the calories of the fuel. A tunnel kiln with wagons utilises, at 1,000°, 80 per cent. of the calories; at 1,250° this number falls to 50 per cent., and between 1,360° and 1,400° it scarcely reaches 40 per cent.

My tunnel kiln at 1,250° utilises 78 per cent., and at 1,450° 70 per cent. of the calories of the fuel; if the length be sufficient it will utilise more than 85 per cent. of the calories; it is therefore the kiln which gives the greatest thermal efficiency among those which are employed in industry.

Heating of Materials.—The materials which have been successfully fired in this kiln include the following: (1) At 1,250°, stoneware and alumino-silicate refractories, with a consumption of 50 kilog. of fuel per ton of fired products. (2) At 1,350°, porcelain insulators, with an expenditure of 61 kilog. of fuel per ton of goods, including the supports. (3) At 1,450°, porcelain insulators, cements, bauxite products, corindite and chromite, with a consumption of 75 kilog. of fuel to the ton. (4) At 1,530°, magnesia products, with a consumption of 105 kilog. of fuel. At the same temperature the firing of silica bricks requires a longer time and the consumption is raised to 130 kilogs. per ton; the products are perfectly fired and homogeneous; there is no loss in the firing, of which the duration from the setting in the kiln to the drawing does not exceed 5 hours. This kiln is the one which gives the best results for the firing of such awkward materials as silica products.

The heating of these kilns is carried out equally well by means of gas producers. However, with this process, care must be taken that the gases lose no part of their heat before penetrating into the kiln; in order to avoid this loss the gas producer and gas passages are completely insulated by the processes employed for the kilns.

Deliveries from the Kilns.—The kilns represented by Figs. 5 and 6 can deliver per 24 hours, from 15 to 25 tons of goods according to the density of these goods and the conditions of firing: the chief principle of their firing, even with direct flame, being radiation of heat, it is therefore necessary not to

increase too much the capacity of the wagons if it is desired to obtain a sufficiently uniform temperature in the firing. For a

Fig. 8.

production greater than that indicated above it will be preferable to employ a two- or three-way tunnel placed in a single chamber of ferro-concrete.

According to the materials to be heated, the system of heating, the forms and dimensions of the kilns, and the refractory materials used vary, but the system of rolling and the principle of insulation of the kilns on all the surfaces is invariable.

I omit details regarding accessories such as dryers, tracks for the return of the wagons, apparatus for measuring temperature and pressure in the kilns, analysis of gases, ejection of the combustion gases, apparatus for driving the wagons, etc.

To sum up, these new kilns with movable bottom present the following characters: They are simple, not very costly, and require little manual labour. Their length is not appreciably great, and they are available for high temperatures; in particular they have solved the difficult problem of firing silica products. They consume less fuel than the other kilns hitherto employed.

Note.—The tube and tunnel kilns have been patented.

DISCUSSION

Mr. JOSEPH BURTON:—We all realise, I think, that this question of firing is a very serious and important one for the pottery industry. It has now become a very much more critical question because of the present high cost of fuel, and any savings that can be effected nowadays, which can be reckoned either in crates of ware or in yards of tiles, must be quite double what they were a few years ago. The question of economy in fuel consumption is a much more important one than it was before the war. Then again, there is also the question involved here of a more regular type of firing for ordinary pottery ware than that which has been in general use. Intermittent methods of firing are always bound to be subject to great irregularities, and although these irregularities have been overcome in a very remarkable degree by practical firemen, in many cases they still exist. We still have our ring ware and our middle ware, and our very considerable variations in the oven, and it is a difficult problem to decide really whether the firing of ware in big ovens is, on the whole, better than that in small ovens—whether it is better to have a big chamber which offers a larger zone, or a small chamber where it is possible to more easily regulate the temperature. We must all agree that in the tunnel kiln we have a means of getting a temperature which is very much more under control, and is fairly even throughout the whole mass of the ware, because, as a matter of fact, the ware is pushed through, as it were, in a thin stream, and therefore there are not the possibilities for variation in temperature that we are subject to in the ordinary intermittent firing. All

these questions go to make the tunnel kiln problem a tremendously interesting one, and although Dr. Bigot has scarcely added anything to the general principle of tunnel firing, he has sought to bring before us important savings that can be effected by dispensing with the complicated mechanical parts in a tunnel kiln, which involve a loss of heat. In the direct-fired tunnel kiln, where the products of combustion are allowed to enter into the oven and get amongst the saggars or ware, it is necessary not only to have a very carefully adjusted sand seal that will separate the tunnel from the carriage way underneath, but also to have some means of keeping the track cool, such as a second tunnel underneath through which a current of air can be circulated, and it is Dr. Bigot's achievement here that by the introduction of fireclay refractory balls, he is able to provide a movable bottom, so that the whole thing can be contained in one tunnel even for high temperature firing. By this means he saves all the complications of mechanical and metal parts, and effects a tremendous economy in loss of heat. The one thing that I was a little disappointed with when I first read the paper was that it did not seem to me, as it stands, to offer everything that we want as pottery manufacturers, or rather, that the kiln has been worked out up to now to meet the firing of refractory materials and things that can be pushed through quickly. Many of us would shiver, for instance, at the thought of passing ordinary earthenware through the oven in five hours—a figure mentioned in the paper—whereas, for some classes of material, that may be a perfectly satisfactory period. I should like to know how Dr. Bigot's figures of fuel consumption compare with those of ordinary tunnel kilns in the event of lengthening the time taken in passing the ware through. I am inclined to think they would still show an economy, but whether the same economy is, I think, a little doubtful. There is another point, and that is the question of the loss of heat in the goods as they come through the firing zone. Even with a fairly long tunnel kiln, and a fairly long cooling zone, the wagons and the goods are drawn out very hot. Dr. Bigot throws out the hint here which has been put to practical use in various tunnel plants that some of this heat should be utilised for other purposes, because only a small portion of it is necessary to heat up the air which is requisite for the adequate combustion of the gases in the combustion chambers. This is a question in connection with tunnel kiln firing which needs to be seriously looked into. It seems to me that if tunnel kiln firing is to be successful then the works will need to be built round the kilns; everything will have to be arranged on the factory to suit the kilns. This applies not

only to the dipping, the placing and the drawing, but also to the utilization of the waste heat at the end of the tunnel, because, if you are going in for economizing heat, there is absolutely no excuse for throwing any away at that end. The expense of putting down a plant of this sort, and of reorganizing the work for it, is so considerable that everything possible will have to be done to make the plant as efficient as possible. Seeing that firing is the most important and crucial thing in the whole process of pottery manufacture, it is quite a right and fitting thing that the other departments should be made to adapt themselves to it, and it seems to me that this will have to be done before tunnel firing can give the advantages which it really has to give. We must remember that although tunnel kilns were first used 150 years ago in France, and in this country for bricks some 60 years ago, tunnel firing may still be considered to be in its infancy, and there is room, as Dr. Bigot has shown, for considerable improvement, and as soon as we get it into more general use we shall probably find that very great improvements are still possible. I do not think that we shall be exaggerating if we say that this question of firing is the most important question that we, as potters, have to consider, and therefore I feel that we ought to be very grateful to Dr. Bigot for bringing it before us in this very admirable paper. I wish it had been possible for him to be here so that he might have enlightened us on some points, such as, for instance, the absolute suitability of his kiln for the firing of ordinary earthenware, and others matters which he will perhaps elucidate in his written replies, which will no doubt be published afterwards. I have pleasure in moving a hearty vote of thanks to Dr. Bigot for his very interesting paper.

Mr. F. TURNER:—I do not think that I read the paper quite in the same way as Mr. Burton. Firstly, with regard to the question of the length of time. I fancy that Dr. Bigot intended to state that the goods passed through the tunnel in fifty hours. Does not the figure of five hours refer to his experimental kiln rather than the tunnel? It seems inconceivable that with any length of tunnel kiln goods can be passed through from one end of the kiln to the other in five hours. In any case that would certainly not suit potters. We know, of course, that there are tunnel kilns which are being successfully used, but they entail a considerably longer time than that. There are one or two things that we would have liked to have asked Dr. Bigot. His idea, for instance, of a movable platform for the wagons seems admirable, but I do not see any mention in the paper of the probable length of life of this system, which

is rather an important point when dealing with a tunnel kiln, where a breakdown is considerably worse than with an ordinary oven. You may have to stop the plant, which may mean two or three weeks, and considerable loss. I think a little inform-taion on that point would have been useful. Then Mr. Burton mentioned the fact that in this tunnel kiln you would certainly get a more even temperature than you would with the ordinary oven. Well that, I think, requires some little proof. In the paper we do not seem to have any. Neither is there any mention in the paper of the temperatures in the various parts of the tunnel. That, again, would have been useful, because I do not know that experience teaches us that the temperature always *is* even and regular, even in the small space of a tunnel oven. We may encounter variations quite as great as in the ordinary type of oven. It does not necessarily follow that these variations are such as will be prohibitive, but we shall probably find they are there, all the same. Some information from Dr. Bigot on this point would be helpful. I quite agree that in order to take full advantage of tunnel ovens, when building a factory, one needs to start by putting the oven up first and building round it, because there is no doubt that there is a lot of heat wasted in any type of oven which could be advantageously used provided that you had the means of using it advantageously. There is a lot of heat which runs to waste because your plant is of such a character that the heat cannot be economically transferred to the place to be heated. That is not the fault of the kiln, of course, but the fault of the plant. It is quite true that tunnel kilns, from the ordinary potter's point of view, are as yet in their infancy, and I am not at all sure that the main problems are altogether surrounding the question of fuel consumption, although it has been demonstrated several times, and experience tells us, too, that there is considerable fuel economy with tunnel ovens. That, to-day, is of great importance. It was yesterday, even before the price of fuel was what it is, because, if at any time you are using a ton of coal where half a ton would do you are wasting half a ton, and waste, whether material is cheap or dear, is waste. If you can save waste you are doing good, and I think that tunnel kilns will undoubtedly save fuel. But there are, I think, other problems attaching to tunnel kilns which are strictly tunnel kiln problems, and I am afraid that some of these will only be found out by experience. I am glad that we have had this excellent paper by Dr. Bigot, because I think it may stimulate still further an interest which I believe the National Pottery Council already has in this matter to tackle the problem—really tackle the problem—and do the best they can with it.

It is a problem which really needs tackling rather by a Council of that description than by the individual manufacturer. Unfortunately the individual manufacturer who is tackling a problem of this sort is often losing his money, unless the thing is proved a complete success, and it is rather unfair, really, that any single manufacturer should spend his thought, his time and his money to make a decent thing for somebody else. If the effect of Dr. Bigot's paper is to stimulate a concerted interest in the subject some real benefits will undoubtedly accrue, and therefore we are extremely indebted to him for his present paper. I have great pleasure in seconding the vote of thanks which Mr. Burton has moved.

Mr. C. W. THOMAS:—I have been very much interested in Dr. Bigot's paper for two reasons. First, because I consider that the economising of fuel and of labour is of vital importance for the clay industry, especially for the heavier branches of it, such as building bricks and general refractories. Second, because of the extreme simplicity of the constructional methods adopted.

I have always considered that, to be successful in the ordinary brickworks, a kiln must be constructed in the simplest manner, of materials readily obtainable, with no parts that are liable to rapid deterioration through heat, and with a system of control free from all complications, whether of valves or flues.

All these conditions seem to be fulfilled in Dr. Bigot's kiln, with the possible exception of the moving floor.

I am not quite convinced that the refractory balls will withstand, for long, the weight and the rolling action, at the temperatures they would be likely to reach when firing goods to 1,400° C. or over. It seems to me that should one of the balls split during its passage through the tunnel it would block the groove and stop the motion of the following balls, and thus cause serious displacement of the moving slabs, with the probable stoppage of the working of the kiln. There seems to be no provision for dealing with an accident of this sort, but possibly Dr. Bigot has provided for it.

I notice that the length of kiln suitable for burning bricks to 1,450° C. is given as 50 metres, and the time for firing silica bricks to 1,530° C. as five hours only from setting to drawing.

Both these are so very much less than one has been used to think necessary in other tunnel kilns that there must be some special reason for the reduction which is not apparent on the face of it. The latter time seems too short for the burning to be completely effected. Possibly the special cooling arrangements might account for it to some extent.

Another point which occurs to me is, that while ordinary size bricks may be dealt with in this way, the larger special shapes, which run up to over 200 kilos. in weight, would require quite different treatment and much longer time.

I should be interested if Dr. Bigot would give some idea of the size of tunnels, and also their length, that would deal with a daily output of say 100 tons of fireclay bricks and special shapes, running from the ordinary $9 \times 4\frac{1}{2} \times 2\frac{1}{2}$ up to $42 \times 12 \times 6$, and containing an average variety of shapes and sizes.

Finally, does Dr. Bigot consider that suitable floor slabs and balls for the moving portion can be made from the materials available in an ordinary fireclay works in this country?

Mr. W. DONALD:—In the first place I want to limit myself entirely to the firing of magnesite products in Dr. Bigot's kiln, and I would like to know where I can obtain samples of the fired magnesite bricks. Secondly, I would like to know whether I can see one of these kilns in daily practice firing magnesite bricks, and in the meantime to know the period of months or years that that kiln has been firing magnesite bricks, and to know approximately how many of these bricks have been fired in that period. I would also like to know approximately the capital required for such kilns, and the monthly or yearly output that such a kiln could give for that capital expenditure. I would also like to know what depreciation has been found to be required to cover the upkeep of these kilns, and especially of the carriers. Lastly, I would like to know what percentage of breakages and rejects there are in the magnesite bricks that have been fired in these kilns. I note that the tube and tunnel kilns have been patented, and I would like to have a reference to the patent specifications. Under the paragraph headed "Heating of Materials, section 4," Dr. Bigot says that at 1,530° C. magnesite materials were fired with a consumption of 105 kilograms of fuel per ton of material fired. Such a consumption is approximately 8 cwts. per thousand bricks of standard size $9 \times 4\frac{1}{2} \times 2\frac{1}{2}$, and, judging by this and from the other facts that Dr. Bigot states in his communication, the kiln seems to be one that should have the careful consideration of all manufacturers of highly refractory materials, and I am ready to go into the matter seriously if I can have sample bricks for comparison with the bricks that we fire ourselves in our kilns, and if the other information is made available.

Mr. S. T. WILSON:—Since the amount of heat lost from the outside surface of an oven depends upon the difference of temperature between the outside surface of the oven and

the surrounding atmosphere (whatever the coefficient of conductivity may be) it follows that the intermittent oven loses its heat from this source in an increasing amount as the oven gets hotter. Ultimately equilibrium is reached when the heat lost by conduction, radiation, and that carried away by the products of combustion is equal to the amount of heat given out by the fuel in the firemouths. This sometimes happens in ovens where the firing has been prolonged through some reason or other, and occasionally the temperature required in the oven cannot be reached. It also follows for the same reasons that the quicker the oven is fired the less the loss from this source.

If we refer to the firing curves *A* and *B*, intermittent oven fired with a 9 in. crown covered with 10 in. of sand, and compared with the same oven where the sand is replaced with 6 in. of insulating powder, I should have expected that if all other things were equal, except this difference due to the different rates of conduction, that the difference in rise of temperature inside the two ovens would have been equal, until such a point was reached that it was necessary to go steady for the proper firing of the goods.

Take the curve *B*, which represents the rise in temperature with time during firing when the crown was insulated with 6 in. of non-conducting powder. This shows a rise of 150° C. above that in curve *A* in the first three hours, this is the amount of the total difference in temperature at the end of the firing.

The difference between curves *A* and *B* at this point is such that it seems incredible for it to be due to the difference in the conductivity of the sand and non-conducting material. If this is not due to this reason then if the oven represented by curve *A* had had the same start, the length of time for firing to 1,320° C. would have been less and higher temperatures could have been reached with less fuel.

The longer the time of firing the greater the loss from conduction, etc., therefore if we push an oven during the first few hours the higher the temperature to which we are likely to attain, and of course less fuel is consumed without considering the difference in the conductivities of the building material.

In the tunnel oven the temperature in the firing zone must be at its maximum at the commencement of actual firing, and these losses from conduction and radiation are so great that unless special precautions are taken to prevent them by insulation, equilibrium is reached at a comparatively low temperature.

The use of powders as a means of keeping, as it were, a wall of still air for the purpose of preventing these losses from conduction has its disadvantages. If an insulating powder is

placed between the walls of an intermittent oven it will not remain where it was placed, because as the oven is heated and cooled the consequent expansion and contraction allows the powder to sink but does not lift it back again into position. Thus the powder eventually pushes the brickwork out at its weakest point, but the outside brickwork is held in position, and is comparatively cool and therefore stronger than the inside, which bulges in at its weakest point.

Porous bricks seem to be the proper thing to use. The district owes a debt to Dr. Bigot for showing the losses from conduction so well. It is good practice in this district to use 300 kilos. of coal to fire a ton of ware and saggars to about 1,300° C., whereas Dr. Bigot shows that he fires to the same temperature one ton of goods and supports with 61 kilos.

Most ovens (intermittent) in this district are built with 14 inch walls and 9 inch crown, even for 20 feet diameter ovens. The losses from conduction and radiation in such ovens are enormous. In my opinion, with very little insulation, at least 15 to 20 per cent. of the fuel could be saved, without breaking the standard maximum. What is the value of a ton or two of coal in comparison with the value of an oven full of ware?

Dr. J. W. MELLOR:—I have been disappointed with the way in which the losses of heat by radiation, conduction and so on, are accounted for. The data seemed to me to be vague and uncertain. So far as I can see the most satisfactory way of estimating what the fuel in an oven is doing is to find out how much is actually used in firing the ware itself. The rest must represent non-productive heat—the dead losses of the oven so to speak. In an estimate made some years ago for a china biscuit oven under normal conditions, the amount of coal actually used in firing the ware itself was $1\frac{1}{2}$ per cent. That is to say, for every 100 tons of coal used in firing china biscuit ovens, $98\frac{1}{2}$ tons are not used in firing the ware. Some of this coal may be doing necessary firing, such as heating the brickwork, the saggars, the bedding flint and so on, but it is an incredibly small percentage of the fuel that is actually used. Consequently, almost any scheme of saving fuel would do something towards diminishing the tremendous loss. We must remember in comparing notes of fuel saving that the thermal efficiency of an oven may be estimated by different methods with very different results. In my method the heat actually utilized in firing the ware is measured. The rest is loss. The history of gas firing, particularly in this district, is very interesting. So far as this district is concerned I think it is as instructive as it is interesting. The time is not opportune just

now for going into that, but it has some valuable lessons, even though they may have cost a few thousand pounds. I looked amongst my records collected on the Society's French trip, and found some notes and data respecting a tunnel kiln. This particular kiln produced 48 cars of ware every 24 hours, at an average of 40 saggars per car, equal to approximately 2,000 saggars per 24 hours. This is equivalent to one glost oven, firing to about cone 03, every 24 hours, with a coal consumption of 2½ tons of slack per 24 hours. The kiln had scarcely been seriously repaired for ten years, the only attention that was necessary being minor repairs to the wagons about every two or three weeks. The kiln was about 60 yards long. A sketch from a photograph is shown in the diagram.

Mr. BERNARD MOORE:—At Luneville, in France, they have two tunnel kilns on the same principle, but rather larger. The truck holds twelve bungs of ordinary saggars, and the saggars are placed nine high, each truck giving an output of say 108 saggars. They run the trucks through at the rate of one per hour, so that approximately the output is equal to about five 17 ft. glost ovens. One of the kilns is coal fired, the other gas fired. The gas fired kiln is longer than the coal fired one. The Luneville Co.'s records, as compared with the old type of oven which they employed—I am giving you now figures that are five years old—showed an economy of about 61 to 62 per

cent. so far as coal consumption was concerned. There was a sand seal, and the trucks were rather large, with plenty of room underneath.

Mr. W. J. REES:—As previous speakers have pointed out, this question of economical firing is important, not only to the pottery industry, but also to the manufacture of refractories. I think that in view of the necessity for reducing labour costs the problem of tunnel firing will have to be seriously looked into by manufacturers of refractories. The really novel feature of Dr. Bigot's kiln seems to be his rolling way. I would like to have some information as to the life of this rolling way. It seems to me that Major Thomas, in his written contribution to the discussion, touched upon a very vital question, viz.: that a breakage of one of these balls might be very serious indeed But in any case I would like Dr. Bigot to give us some information as to the life and general behaviour of this rolling way. I understand that there are already tunnel kilns in operation in France in which this principle of insulation is used to a considerable extent—tunnel kilns of very much greater output than the one instanced by Dr. Bigot. One of them has an output of 70,000 to 80,000 silica bricks per week, fired at cone 12. The bricks seem to be satisfactorily burned, and to be rendering good service in the steel industry of France. Like other speakers, I am surprised at the short time of firing referred to by Dr. Bigot, and I would like to know to what extent the conversion of the quartz is effected in this period of five hours. It seems to me that the time mentioned is far too short for the satisfactory burning of a silica brick. It has been a particularly interesting paper, however, and I am of opinion that papers of this type will do an immense amount of good to the industries.

Mr. CUTHBERT BAILEY:—I quite agree with the criticism that Major Thomas has brought forward, that the possible crushing or splitting of a ball might cause a stoppage of the whole process until the obstruction is removed. But the main thing that astonishes me is the length of this kiln. On the last page of his paper Dr. Bigot emphasises the fact that it would be desirable if the 15 metre length between the fireplaces and the exit flues for the gases were doubled. After accepting that double length of 30 metres he still puts down the total length of the kiln at 50 metres, which leaves, say, 10 metres for heating up the goods from the entrance to the firing zone, and 10 metres after leaving the firing zone to the exit. I am surprised that would be satisfactory even for solid bricks, but

it would be certainly fatal for pottery goods, for which gradual rise of temperature and gradual cooling is an essential condition.

Mr. A. FIELDING :—I quite agree with what Major Thomas has said about this rolling action of the balls. I think if that is absolutely safe it will get over the difficulties of the present tunnel ovens in respect to the irregularities of firing. The present tunnel ovens are all fired from the top and sides, and the bottoms are difficult to "get up." I suppose at the present time the bottoms of the trucks are absolutely useless. This principle of rolling balls I have seen myself in South Staffordshire. They were employed in kilns to heat up to 900° C., and they have been at work for years. If something similar to that could appertain for glost oven heats we should have a solution to a big problem, for there was no breaking about them ; they were made of a special sort of material, which I was assured never gave any trouble, in spite of the fact that four or five tons of goods were being carried on each truck. If this principle of roller balls is absolutely safe I think that this tunnel oven of Dr. Bigot will prove far and away an improvement upon anything on the market at the present time, and will overcome the difficulties under which we are suffering just now. I feel that it behoves this district to seriously tackle the problem, and to lose no time about it, because there are many manufacturers whose goods lay themselves out to an oven of this type, in which case there could be a great utilization of some of the waste heat. In respect to that from the cooling zone experts tell me that there is not sufficient to justify going to the expense of putting in apparatus to distribute it, but I question this and shall try it the first convenient opportunity. There is much more from the firing flues, which deliver at about 500° C., although there might be some difficulty in using this, owing to its impregnation with gas.

Mr. J. BURTON :—The question of these rolling balls is a particularly interesting one to me. Some five or six years ago an Italian called upon me with some plans for a glost tile plant that has since been adopted more or less by one of the tile firms in this country. It consisted of a series of small tunnels, a whole battery of them, in a plant which was perhaps as long as the width of this room. The tiles were pushed in at certain periods —I think every twenty minutes—and simply slid along upon a support of fireclay ridges in the bottom. The thought struck me afterwards that I might get the same results with a similar plant but using fireclay balls. But I dropped the idea because

it appeared to me almost a toy, and also because of this very difficulty which might arise in the splitting of the fireclay balls. I said to myself also: It will be necessary to have a carrier in one piece. That makes the plant very small, and I think that was my chief criticism of Dr. Bigot's paper when I first read it and perused the diagrams of his plant; the plant is on such a small scale. I think, too, that you must have the bottom or truck in one piece of fireclay. If then one of the balls split or one of the fireclay bottoms break the whole system will jam. The general idea is only new as applied to high temperature kilns, and it is very interesting that Dr. Bigot has made this principle successful. But it is, so far as I can gather, only upon a small scale, and he seems to admit this, for he says: if you want an increased output you must put down more kilns. The time of firing, too, is accounted for to a certain extent by the fact that it is only dealing with comparatively small units. It is possible to fire a small piece or quantity very much more rapidly than a large piece or big mass of ware on a truck, in which case it takes a considerable time for the heat to penetrate through the mass. The outside pieces protect the pieces further away from the heating or radiating surface. Dr. Bigot claims that the bulk of his firing is done by radiation, and that is the reason why he is firing very small quantities at a time through his tunnels. There again he reduces the danger of the balls splitting, because there is not a very great amount of weight on the bed, neither is there the same chance of the movable bottom breaking. It will be very interesting to hear what Dr. Bigot has to say as to the practicability of enlarging his plant in order to make it a practical thing for ordinary pottery purposes. Major Thomas very rightly brings up that point with regard to the bigger pieces. The bigger the pieces the longer the time required for firing. Of course it would be quite out of the question to think of firing a fireclay block $42 \times 20 \times 12$ in so short a period as five hours, of which only about $1\frac{1}{2}$ hours would be taken up in the really hot zone at all—perhaps less than that. Coming back for a moment to the other question that was brought up by Dr. Mellor, the tunnel kiln that he saw in France, it is similar in construction to what I myself have seen in Montereau. These kilns, when they are applicable, are extremely efficient. I remember seeing one in Silesia firing hard-paste porcelain. It was a long kiln, coal fired. The fire-mouths were on the outside near the centre of the tunnel, which was some 300 feet long, and it was used to fire ware to a temperature of approximately 1,400° C. It was used with apparently very great success.

Mr. J. C. Bailey:—I quite agree with Mr. Burton that the proper way to begin to apply tunnel firing is to build your factory round your tunnel, and there is another thing to be taken into consideration, and that is, what you are going to produce. Because it seems to me that it is perfectly clear you could not use one of these ovens, or any oven, under the conditions that one of these papers suggested, viz.: blocks of ordinary bricks $9 \times 4\frac{1}{2} \times 2\frac{1}{2}$ and very large blocks. You are probably aware that our firm is building at Lambeth one of these Faugeron or Montereau kilns. I shall be interested to see how it goes on. Just before the war I had occasion to go to Milan, and I remember a visit that I paid to a factory of which the son of my old friend, M. Jules Richard, was a director and president. He was very good, and took me round the whole of the place, a most interesting factory, all on the ground floor. They were manufacturing dinner, tea and toilet ware, together with some very small pieces of sanitary ware. As I walked round the factory I discovered that they had a tunnel kiln, which made me still more interested. When I came to the end of the kiln I found that it was full of wagons of bricks. I asked him what this kiln was, and he replied that it was a Montereau kiln which they were not now using. He went on to explain that it was very difficult to use a tunnel kiln with a miscellaneous lot of goods such as theirs. He took me to the centre of the kiln and showed me a large slate. He said, "We had a man, but we lost him, who was able to see what was put on a saggar, go to this slate, and estimate the amount of time that particular truck ought to remain in the firing zone." My friend said, "If we had one size article the matter would be quite simple, but, with a miscellaneous lot of goods such as we have to deal with, we have to watch carefully what is put on every truck, and then estimate the time that this truck shall remain in the firing zone." We sent over an expert to Montereau to see the kiln which we are now building at Lambeth, and we found there that they are putting 6 in. muffins and teas through the kiln, but that all the ordinary general earthenware of the factory is being fired in the ordinary intermittent ovens. That, I think, will illustrate the difficulty of firing different sized pieces in the same time. Therefore, I feel that this is a matter which needs to be taken into careful consideration. I feel that to get the maximum advantages out of a tunnel kiln you will not only need to build your factory round your kiln, but you will also probably need to standardize your productions, and specialise in one or two particular articles.

A Member:—Was this a biscuit tunnel?

Mr. BAILEY:—No; a glost. It was not used for biscuit at all.

Mr. B. J. ALLEN:—I think it is very unfortunate that Dr. Bigot is not here, there are so many questions we should like to ask him. The paper is full of interesting paragraphs, but not so full of the information that we desire. Dr. Bigot says in one place that, thanks to special arrangements, the fired products can be cooled pretty rapidly. We should like to know what those arrangements are. In another place he says that the kiln can be constructed to fire small lots, whereas other tunnel kilns can only be economical with large quantities. The difficulty some of us are "up against" is the fact that the output from a tunnel kiln is not sufficient to justify the expenditure as compared with muffle kilns used in the enamelled fireclay industry. I think that Dr. Bigot's kiln is limited in capacity by his method of heating. I remember that some eight or nine years ago identically the same principle of recuperation was applied to a muffle kiln firing enamelled fireclay goods. We get an intense heat with a minimum of fuel, but the heat was very local. The goods in the vicinity of the firebox were nearly melted down, whereas, farther away, the ware had hardly been touched. So that it seems to me that the method of heating the kiln imposes limitations upon its dimensions. Then with regard to the question of saving calories by the use of fireclay rollers instead of trucks, I cannot quite see where this comes about. If the trucks are fitted with an insulated pad I do not see how you can lose more heat through the trucks than you would through a rolling platform.

I think it would be a big help to designers of tunnel kilns if they had some standard to work upon, and tried to work out some sort of a tunnel kiln that would meet essential conditions. For the firing of heavy pottery it seems to me that it would be the reasonable thing to heat up the goods slowly to 800° or 900° C., then fire up as rapidly as possible to the necessary temperature, cool down rapidly back to 900°, and then slowly to the drawing stage. I should like to know how far these conditions could be met in Dr. Bigot's kiln.

There is one great difficulty in the adoption of tunnel kilns, and that is the space they occupy. Very few factories are planned in a way which permits of their erection without big structural alterations, and the question arises whether it is not possible to get the same thermal efficiency from muffle kilns. The same principles of insulation and recuperation can be applied as to a tunnel, and if the waste heat is utilised for steam raising and drying, etc., the difference in economy must be very small.

With regard to Dr. Bigot's remarks on the thermal efficiency of his kiln, it appears to me that the greatest thermal efficiency would be obtained by employing the surface combustion principle, using diaphram apparatus arranged in rings or panels under separate control, so that the length of the firing zone might be lengthened or shortened to suit the pottery being fired. The loss of heat by radiation from the walls of the firing zone would be nil. Dr. Bigot's views on this subject would be interesting.

Mr. HAROLD PLANT:—Whilst we are on this question of tunnel kiln firing I would like to remind the meeting that yesterday was an epoch making day in the history of this district, inasmuch as it marked the federation of the industry, with a view to enabling us, as an industry, to go in for the very best, and experiment in many ways so that we may arrive at that which shall be mutually useful to us as manufacturers and workers. It remains to be seen how far The Ceramic Society can help us in this direction, but I feel that we need to get to work immediately by calling the experts together to talk over this question of tunnel firing in all its various aspects, and thus endeavouring to get such practical proposals as will enable us to make a start. We seem to be talking tunnel kilns and thinking tunnel kilns from the Dressler to all the peculiar names which some of our friends seem to be able to so readily call to mind, and I am sure that everyone of us is itching for something that will give us efficiency. Personally I do not care whether it is Dressler or Bigot, or a local manufacturer, if he will give us the kiln we want. I do not know how far this meeting can act towards urging the federation to get to work quickly, but that is what I am anxious for.

Mr. J. W. HARTLEY:—My impression of Dr. Bigot's system of running a platform on fireclay balls is that the balls and the grooves in which they run will wear, and that when it is found necessary to put in new balls the experience will be that the balls will not fit the grooves. This would mean that the balls would have to be renewed from end to end. If the grooves are fitted to the balls when new, as the balls wear down the grooves will also lose their form, so that when the new balls are installed it does not follow that because they fit the sides they will also fit the bottom. Then again, as Mr. Allen has remarked, the kiln is so small that it would be quite unsuitable to the needs of this district. Further, Dr. Bigot is burning the gas right inside the kiln. How is that going to suit the potters? I doubt very much whether that would suit the majority of

them, as they are careful enough as it is at present to keep the gases as far removed from the ware as possible. It seems to me that some other method might be adopted, which would admit a larger size kiln, and a better circulation of flues. Along with a manufacturer my firm has worked out a scheme whereby the length occupied by a tunnel kiln might be considerably reduced, and so make it possible of installation in a factory where 230 feet of space is not available. But it is necessary that experiments of this kind should be carried out not by any one manufacturer, but by the federated potters. If they do not take the matter up in a collective manner it is hopeless to make much progress. I should be very glad to render any help I can, and so, too, would my friend, who is interested in the kiln in question. We should be very glad to declare what we have to say in the matter, and then leave it to the federated potters as to whether they would care to proceed with experiments on those lines. I should like to see the whole thing made a success for the good of the Potteries as a whole.

Mr. J. H. MARLOW:—I am interested in the subject of gas firing, and have been for the past 29 years. I studied this problem in America for a number of years, and when I came to the Potteries, I at once commenced to put my ideas into practice. Having many difficulties to face, and with such hands as I had, I started to build a tunnel oven that I thought would suit the pottery manufacturers. Of course the war was on, and at first we could not get materials. Our orders were taken first by one firm and then by another, and turned down six months afterwards on account of Government work, but finally we got the material required, and we fired an oven. We ran it for three or four weeks very successfully, and then we were beaten by the water. The heat generated steam from the water, with which we are very much troubled, the same permeating the kiln, eventually bringing down the temperature of the kiln from 1,100° to 800° in a few hours. We have now got over the difficulty by raising the producers above ground, and I am hoping in a few weeks to be able to produce a tunnel oven that can be used by a small manufacturer just as satisfactorily as by a large firm. It must not be overlooked, of course, that everyone has not a works in which he can put down one of those great long tunnel ovens of which we have heard so much. In my kiln I have combustion chambers on either side, and I have, running from the combustion chambers, a number of rings or flues. The heat passes over the top, like our muffle, from one side to the other, and what I claim for the kiln is, that being of a muffle type, it will have an increased life, and you

will be able to pass through it an enormous amount of ware. So far as the heat in the ground is concerned, I feel sure that you will not have any trouble with it. I hope shortly to be able to invite the members of the Federated Association to come over and have a look at it.

A MEMBER:—What difference is there in temperature between the bottom of a truck and the top? And what is the height of the tunnel?

Mr. MARLOW:—I do not find that there is much variation. The height of the tunnel is 7 ft., but I could build it 10 ft. just as easily. When you see it you will agree with me, I think, that it could be fired with the same heat, and yet made to carry double the quantity of ware that we do to-day. The total length of the kiln is 161 feet.

Mr. J. WILLIAMSON:—I have listened to the lecture with very great interest, and would like to make one or two remarks bearing on the subject. In the first place it has been stated by Dr. Bigot that he can fire certain goods in a certain time, but the period of time is so ridiculous that most of you will agree that there is something wrong, and I do not think it would be fair to Dr. Bigot that he should be criticised for what may after all prove to be a printer's error—five hours for possibly fifty hours. It seems to me to be totally impossible to fire goods within such a short space as five hours. Many claims have been made by Dr. Bigot, some of which are far in excess of what has ever been claimed before, and some of these seem to me to be far too ambitious, therefore I am sorry that he was unable to be present to give us information on some of these points. To refer for a moment to the kiln he illustrates in his diagrams 2a and 2b. Here he shows a small kiln, with an internal working capacity of nearly two cubic feet, which will fire to 1,700° in $5\frac{1}{2}$ hours with ten cubic metres of coal gas per hour, and having an efficiency of 70 per cent. Personally, I cannot see how he arrives at that. If you work backwards from the figures given, and estimating the efficiency at 70 per cent., you will find that the calorific value of the gas is not more than about 1,000, and if gas of this calorific value is used surely it must have been war-time gas. I should like to know the analysis of this gas before and after burning, and the temperature, previous to entering the burner, of the recuperative air, and temperature of exhaust gas. Another point that must not be overlooked in dealing with this problem is that on a small scale you sometimes get exceptional results, and

that when you try later on to equal these results in practical working you find it is impossible to get anywhere near the results attained in the laboratory. Then there is the question of insulation. Dr. Bigot claims to have secured certain results by insulating the top of the kiln. Again, I am disposed to look upon this with a certain amount of suspicion. It is true, of course, that there has been little or no attempt in the past to insulate existing ovens, and there seems to be no doubt about it, that if this principle of insulation were to be applied in a proper and systematic manner to existing kilns, a great deal of economy would be effected, and a lot of talk about tunnel kiln firing would disappear. But, somehow, nobody seems to have given it a serious trial. If Dr. Bigot can satisfy the manufacturers that he can indeed get the results he has claimed, I am certain that he would render the manufacturers a very great service indeed, and that they would be happy to take him on.

With regard to continuous firing, a great deal of attention has been bestowed on the point of insulation, but even with the best insulation possible, with a thickness of nine or ten inches on the arch, you will still have a certain amount of radiation which it is impossible to avoid, and it does not matter how you try you will still have to submit to this loss. Eventually you reach a point where the cost of insulation far and away exceeds the gain.

Coming to the question of refractories, it seems to me that to carry a load on a refractory material is contrary to all modern ideas of engineering. We know that refractory materials are abrasives, and I can associate myself with the remarks of Mr. Hartley that this seems to be one of the chief defects of Dr. Bigot's system. The wearing of the balls is a serious question. Assuming that the balls are 2 in. in diameter, they would wear down very quickly, and the replacing of them would be a difficult matter. Apart from wearing, there is also the possibility of a ball breaking, in which case it would have to be replaced by an identically similar ball, as Mr. Hartley suggested. But the most serious objection, it seems to me, is that it is well-nigh impossible to make and fire slabs and guarantee them so straight that every ball will take its full and fair share of the load, and if the load should be carried by only a proportion of the balls this is going to lead to disaster.

This brings me to another point. Dr. Bigot claims to have made a refractory material which will withstand a temperature of 1,100° at a pressure of 1,700 kilogrammes per cm., that is, $7\frac{3}{4}$ tons per square inch. If you come to calculate the pressure per square inch you will find it not only reaches $7\frac{3}{4}$ tons

but exceeds that figure, as the load is carried on a series of points. This system has been tried before, but in no case has it proved a success, and I do not think it ever will, because it is contrary to all the best experience and practice.

A remark or two with regard to the type of kiln. Dr. Bigot shows a kiln with the combustion chambers running inside the tubes. This seems to be a simple type of oven, but I would like a few more particulars about the mixing arrangement of gas and air, area of chambers, provision made for expansion, and many other details. It seems to me that the greatest objection to this kiln is that it depends for its heating upon radiation. I believe that when you depend upon radiation alone for getting heat into the centre of a body you are in for trouble right away. I should like to hear from Dr. Bigot how the temperatures compare at top and bottom. The last speaker claimed, I believe, to be able to fire a tunnel which would give the same temperature at top and bottom. I should very much like to see it, because this is contrary to the natural law of heat. It is one of the practical impossibilities. It may possibly be got some time or other as a phenomenon, for which there is no explanation, but that is all.

There is no doubt that tunnel kilns are coming, possibly more quickly than some of us think, but there are a lot of difficulties which have to be settled, and a good deal of thought will require to be given to them before we can get them right. It is essential, therefore, that we should not be sparing in our criticisms. In Dr. Bigot's it seems to me that the whole of the heat is coming from one side of the chamber—the inside—and my experience has been that when you have one side of a chamber which is doing the whole of the work, that shrinks much more than the other side which is doing no work at all. I am afraid that it will develop cracks, and that in a short time the chamber will collapse. Then you are in for trouble, and it will be a difficult matter to carry out the repairs.

Further, it is a very small kiln, and that is one of the principal objections to it. But to enlarge the kiln and depend entirely upon radiation seems impracticable.

Dr. Bigot claims that tunnel kilns working with wagons are in use giving a temperature of 1,000° with an 80 per cent. efficiency. I should be glad to know where these can be seen, as these figures seem to me to be on the top side. He also claims to be able to fire stoneware to a temperature of 1,250° with one hundredweight of coal per ton of ware, and porcelain insulators to 1,350° with an expenditure of $1\frac{1}{4}$ cwts., and magnesia products and silica bricks to 1,530° with $2\frac{1}{4}$ cwts. These percentages are so much in excess of what has ever been

claimed before that one is inclined to view them with a certain amount of reserve in the absence of more information to support the claim.

But there has been a lot which has been very interesting in the paper, and if it serves no other purpose than to arouse the interest of manufacturers, and bring them to a realisation of the fact that they are losing a lot of money, it will have done good. There is no doubt about it that tunnel kilns are coming forward very rapidly, and I believe that they are the ovens of the future. There are many ovens on the market designed to meet all spheres of operations, and I am not going to say here which is the best, because I cannot.

Good work has been done in the past by ordinary intermittent firing, but a lot of this has been due to the skill and the care of the fireman rather than to the particular type of kiln used. I often wonder what Wedgwood would think if he could come back to this planet after 150 years and find manufacturers still firing with the same old type of kiln as he did. However, I hope, for the sake of the industry, that the time is not far distant when manufacturers will see their way to adopt the tunnel kiln in its place.

Dr. A. BIGOT:—In reply to Mr. J. Burton; there is a mistake in the editing or in the translation of my article on the subject of the duration of the heating. The industrial laboratory furnace can be heated in five hours; as for the tunnel kiln the duration of firing is much longer. In a tunnel kiln 30 metres long, producing 4 tons of refractory products fired at 1,450° C., the goods are 60 hours in the tunnel. In order to fire silica bricks it is sufficient to keep them 5 hours in the zone where the temperature ranges between 1,400° and 1,500° C., which necessitates a longer tunnel and a total stay of 100 to 120 hours in the kiln.

Until now it was admitted by all tunnel kiln builders that it was impossible to realise economically a tunnel kiln for a small daily production, that the tunnel kiln must be a costly tool and that only important firms with a large output would be able to have such apparatus constructed. The problem has been solved by the use of rolling apparatus in special refractory materials other than clay, of perfect resistance from all points of view, and especially by the rational employment of the best insulators known, which I studied specially, which surround the kiln and eliminate the loss of heat by radiation. The length of the tunnel kiln is reduced by constructing with simple sheet-iron the part of the tunnel on the side of the discharge; the length of the tunnel in sheet-iron should not exceed a

quarter of the kiln. Excessive absorption of heat by the goods I avoid, in great measure, by radiation from the surface of the sheet-iron wall, and it is possible to collect this lost heat.

At the other end of the kiln there is similarly heat lost by the combustion gases which go hot from the kiln. This heat lost at the two ends of the kiln is more than enough to dry the goods for firing. It is then indispensable to fix near the kiln drying rooms in the form of stoves, tunnels, etc. The whole drying and firing apparatus constitutes two fixed groups about which the other workshops should be set out so as to reduce to a minimum the cost of management and labour.

The question of the size of the kilns and regularity of firing rightly preoccupy manufacturers. Tunnel kilns can be constructed of sufficiently large diameter; there are some in existence two metres wide and two metres high which give considerable productions.

Heat is conveyed into the kilns by radiation and by conduction through the goods and the kiln walls; if the volume of goods to be heated is small the temperature is equalised more rapidly than in kilns with large volume. The bottom of the kiln not being directly heated, except in my system of tube kiln, the temperature will be always a little lower in the vicinity of that bottom.

All kinds of products can be fired in my kiln—ordinary pottery, enamel, refractories, etc.—by giving according to the production and the temperature to be obtained suitable dimensions and form. I have not spoken in this lecture of the firing processes, and hope to return to this question later.

Tunnel kilns have made little progress because the study of refractory materials, their conductivity, permeability, resistance, etc., has scarcely commenced. I know of no study on the heat radiating from these materials at high temperature. If my tunnel kiln is a slight advance on others it is because it is based on studies of special refractory materials and on a complete study of insulating materials.

In reply to Mr. F. Turner; the duration of firing I have dealt with in the reply to Mr. Burton. The life of the special movable pieces averages two years. In case of stoppage of the kiln cooling takes place very quickly, because the walls are thin and of materials which have absorbed little heat; cooling takes place in 24 hours, three days are necessary to empty the kiln and to fill it again with goods, so that kindling takes place on the fifth day. During this stoppage, if the kiln is accompanied by drying rooms heated by the waste heat of the kiln, they are put into direct communication with the producer of the kiln, which avoids stopping the producer.

Mr. Turner expresses an excellent idea in proposing to submit the study of the problem to the National Pottery Council. It is in fact impossible for a manufacturer to undertake the expenses of such works. As far as I am concerned, if I have begun this study with some successes I owe it to M. Ch. Guérineau, manufacturer of refractory products, President of the Syndicat du Fabricants de produits Céramiques de France, who, after seeing the results obtained at 1,750° C. in my little recuperating furnace, agreed to run the risks of the construction of my first tunnel kiln.

In reply to Mr. C. W. Thomas; the balls which I use are never heated to 1,400°, the maximum temperature which they can sustain is 1,200° C. At 1,100° they have greater crushing strength than at ordinary temperature. In the future I foresee the possibility of obtaining refractory materials with good crushing strength at higher temperatures, but the trials which I endeavour to obtain have not yet entered into practice.

Two years ago the case of fracture of balls occurred three times without there being any interruption; the balls were broken into two pieces, which were expelled by the old balls; by adapting the rolling to adjacent double balls, indicated by Fig. 5, the accidental breaking of the balls is without importance. I must confess the rolling takes place much better than I had hoped when I constructed the first kiln.

The question of firing simultaneously very heavy pieces weighing say 100 kg., and bricks weighing 3 kg., is easy to solve. The duration of the firing of a piece weighing 100 kg. is longer than that of a piece weighing 3 kg. The heat must have time to penetrate by conduction to the heart of the heavy piece in order to attain the necessary stage of firing. It is therefore necessary to separate the firing of heavy pieces from that of light pieces. This separation will take place in two ways: either the heavy pieces will be fired for a certain number of hours by leaving them longer before the fires, slackening the progress of the wagons, then the following wagons will be charged with light pieces and the speed of travel will be increased; or, if the production allows it, two adjacent tunnels may be used, one for heavy pieces, the other for light pieces.

In order to make 100 tons per day of refractory products, bricks and large pieces, I would construct two parallel tunnels, comprised in the same insulating covering, separated from one another by the insulating powder and each supplied by a single producer, allowing them to be worked together or separately; in one I would fire the large pieces and in the other the small ones; a length of 50 metres would be sufficient for the large pieces and 45 for the small ones, but it would be preferable

to give 50 metres to the two tunnels in order that either may be able to serve for the firing of large pieces; the length of the wagons would be about 1·20 metres.

In a manufacture of this kind I would advise a drying chamber to harden soft pieces, and a tunnel dryer of very simple form and not expensive in order to dry thoroughly the hardened pieces in such a way that on setting them in the kiln they are still hot. The drying chamber placed in the workshop where the soft pieces are made would be heated with heat lost by the goods before coming out of the kiln, and the tunnel dryer with heat lost by the combustion gases on leaving the kiln.

The balls and the slabs, as I have already explained, are made with special refractories, easy to find in England, and each firm using my tunnel kiln would be able to make them in accordance with the information I would supply.

In reply to Mr. W. Donald; I will send direct to Mr. Donald the information he requests, which is of a peculiar order. However, I have to point out that in my tunnel kiln there is not one per thousand pieces broken, no more for magnesia bricks than for silica bricks, because of the slow progression of the heating and cooling. On this occasion I have to describe observations which I made on the duration of firing of products of that kind. Experiments were made with bricks of these products in my industrial laboratory furnace installed at the Conservatoire National des Arts et Métiers. The raw bricks are carried to the stove about 100—110°, then placed at that temperature in the kiln. The heat is raised progressively so as to reach 1,500° to 1,550° C. in five or six hours, the products are held at this temperature for 4 hours, the fire is extinguished, and the whole left to cool gradually during the night. Products thus obtained are perfect and entire. On the basis of these trials, which have always given good results, I recommend placing in the tunnel pieces going hot from the dryer; fractures are avoided at the beginning of the heating and the heat absorbed by the pieces in the dryer is gained.

In reply to Mr. S. T. Wilson; in an intermittent oven the heat lost by radiation represents only a small part of the waste heat; on this subject I gave some numbers sufficiently precise in my lecture at Stoke in 1915. (See TRANS., **14**, 116, 117, 1915.) It is an advantage, as Mr. Wilson says, to heat the oven rather quickly; but to attain the firing temperature of the goods the temperature of the internal walls of the oven must also be raised. If these walls are rather thick they often absorb more heat than the goods to be fired. If, therefore, the greatest part of the oven walls be replaced by insulating bricks or insulating powder, these new materials absorb much less heat

than the ordinary brick, being much less conducting. An intermittent oven furnished with these materials can be heated more quickly and will lose less heat.

In the experiment which I have quoted, and represented by the curves *A* and *B*, there is a point of which I did not speak, the permeability of the materials. I observed that the arch covered with sand was permeable to gases during the firing; a part of the hot air contained in the oven traversed the arch and the bed of sand. When the arch was covered with infusorial silica powder it became impermeable to gases. There can be neither entrance nor exit of gas by the walls in my tunnel kiln, which is sheet-iron on all its faces; as to the powder, contrary to the received opinion, it does not pile up and remains in the place where it is put.

The question of the permeability to gases of refractory materials was studied in 1908 and 1909 by M. Vologdine (see the *Bulletin de la Soc. d'Encouragement a l'Industrie Nationale*). Vologdine found surprising results: certain refractory clay bricks are twenty times as permeable to gases as others. Vologdine cites the case of permeability for magnesia bricks of different origin varying from 1 to 60; he cites two examples of silica bricks having as permeability, the first 3·32 at 1,050°, and the second 192·90 at 1,300° C. These phenomena attracted little attention from furnace builders. It is certain that permeability to gases plays an important part. Unfortunately the studies of Vologdine have not been continued, and he has drawn no conclusions from them.

This whole question has to be taken up again and elucidated. The figures which I gave on the consumption of fuel in my tunnel kiln have been verified at different times and are exact.

In reply to Dr. J. W. Mellor; I wished to give more precise numbers for conductivity, and losses by radiation. M. Vologdine, amongst others, showed interesting results on this subject, but these important questions should be studied anew in a special laboratory well fitted with apparatus like that directed by Dr. Mellor at Stoke.

The figures which Dr. Mellor gives on the subject of the waste heat in an oven for firing china biscuit are conformable to reality. I had occasion to calculate exactly the consumption of fuel in a porcelain oven of Limoges firing table porcelain at 1,410° C. Of 100 tons of coal consumed, 90 are lost; of the 10 tons actually utilised, one-twelfth only serves to fire the goods, and the other eleven-twelfths serve to fire the saggars. The heat really utilised does not reach one per cent.

In reply to Mr. B. Moore; I do not exactly know the Lunéville oven; according to the description which Mr. B.

Moore gives of it I see that it serves for firing at not very high temperatures.

In reply to Mr. W. J. Rees; I have already replied on the subject of the movable pieces to previous speakers. I know there are one or two tunnel kilns in France in which silica bricks are burned, but I have not been able to obtain information as to the consumption of fuel. One of these kilns is a Dinz kiln, provided between each pair of adjacent wagons with a grate on which the fuel is deposited; the system seemed to me defective because it lengthens the kiln excessively and leaves a void among the wagons loaded with goods.

In reply to Mr. Cuthbert Bailey; according to the nature and amount of goods to be fired, and to the mode of firing the length of the kiln will be variable; in that which I described, the length is too short for products fired at 1,450°—1,500° C., but is suitable for products to be fired at 1,250° C.

In reply to Mr. A. Fielding; I think my previous replies answer to the questions put by Mr. Fielding. I consider that my tunnel kiln, thanks to its simplicity and to the economies it effects, will be able to render service to manufacturers of this country, and that there will be always an advantage in utilising waste heat for drying the goods.

In reply to Mr. Burton; with suitable refractory materials the problem of rolling is easy to solve, even for tunnels with great yields. I do not fear the crumbling of balls the diameter of which is proportioned to the dimensions of the movable slabs and the resistance of which is considerable. The system of rolling does not limit the dimensions of the kiln, which can be equal to that of other kilns rolling on metal trollies; this kiln is suitable for pottery and for English porcelain. In proportion as I study the questions of heating I am more and more convinced by my observations and my trials that radiation plays the greatest part in the firing, and that the conductivity and radiating power of the materials of the ovens and saggars should be studied, for in short the goods which are fired in saggars are all heated by radiation.

The kiln which you saw in Germany, firing porcelain at 1,410° C., with fires having mouths, is probably the porcelain kiln of Faugeron; it works well, but I have not been able to obtain information as to the consumption of fuel.

In reply to Mr. J. C. Bailey; the observation on firing different articles in the same kiln is correct, if it is applied to enamelled pieces of very different thicknesses, for the enamelled piece must have attained the desired temperature in all its thickness, and if you manufacture pieces of great thickness, and pieces of small or medium thickness, it would be

better to employ the solution I indicated in my reply to Major Thomas.

In reply to Mr. B. J. Allen; I much regret not being able to attend the meeting and give further explanations in presence of the audience. My replies to previous speakers concerning the cooling of the goods and the dimensions and yields of the kiln will give satisfaction, I think, to Mr. Allen. As to heating economy, it is necessary to add economy in workmanship and of material for setting in.

When the wagons are metallic the fire must be further away, which necessitates a higher furnace; it must be cooled at the lower part; all of which cause loss of heat.

In my tunnel kiln the firing and the cooling are progressive, and I believe that is necessary for the manufacture of all ceramic products.

The tunnel kiln which I described is not as costly as Mr. Allen seems to fear, and for firing his enamelled bricks, about 900° C., I suppose, a kiln 35 metres long seems to me sufficient. I am quite prepared to give him information on the possibilities of insulating his muffles if he will confide the plans of them to me.

Mr. Allen raises the question of heating by surface combustion. That is a most interesting question to which must be joined the question of internal combustion. With these questions are connected that of refractories capable of supporting the temperatures of these combustions and that of refractories susceptible of promoting them. Studies are being made on this subject from different sides, and it is certain that they will lead to interesting results some day or other.

Mr. Plant takes up again an idea, expressed by Mr. Turner, of the National Pottery Council making a study of the question of kilns. In such a short account I have not been able to recall the numerous predecessors who have contrived furnaces, some of which have never seen daylight. Others, like those of Faugeron and Dressler, give very satisfactory results. It is in fact in the common interest to make comparative trials; the observations and criticisms of manufacturers will assist in great measure the progress of kiln building.

In reply to Mr. J. Williamson; the small industrial laboratory kiln of 2 cubic feet can be raised to 1,750° C. in 5½ hours with an average expenditure of 10 cubic metres of coal gas per hour. I have not indicated for this kiln a heat efficiency of 70 per cent. That number refers to a tunnel kiln. The illuminating gas employed had a calorific value of about 4,000 calories per cubic metre.

I have already explained the system of balls and rolling; before constructing it I submitted my idea to a very competent engineer, who declared that it was impossible of realization. In spite of everything its realization was very easy. But Mr. Williamson's objection greatly interests me; he considers that the balls cannot resist high pressure because the pressure is distributed only on one point of each ball, and that too great a number of balls would be necessary for the whole of thse points to form an appreciable surface capable of resisting the pressure. The question brings us back to a problem of elasticity; the ball thus compressed is momentarily deformed just as a billiard ball, allowed to fall on a hard surface, is flattened and rebounds, resuming its shape. I am going to make measurements in this direction with the balls; it is probable that they behave under pressure like an elastic material and that contact is not reduced to a point but to a measurable surface.

There is another point to which it is easy to reply without new trials; the question is the wear of the rolling materials. The constituent pieces are fired strongly, have undergone very great hardening, and the wear is very slight. M. Guérineau's kiln was lighted more than two years ago, and the greater part of the slabs fixed in the way on which the balls roll still exist without appreciable wear; it is a question of good manufacture.

The balls in the kiln travel over one-half the space that the movable slabs do. In a 30 metre kiln, where the wagons are 60 hours travelling over the track, the balls have travelled 15 metres in 60 hours, or 25 cms. per hour; if the kiln is 60 m. long, and the journey lasts 60 hours, the balls travel 50 cms. per hour; this speed is insignificant and explains why the wear of these materials is very slight; and after more than two years experience I consider the rolling system very practical, and if it were not so I would have been the first to abandon it.

I cannot yet give details of the tube furnace; the difficulties of supply and of transport in France, which are not realised in England, have prevented me from meeting the demands for furnaces of the kind intended for the carbonization of wood and coal.

On the question of radiation I maintain my opinion; it is grounded on incontestable facts; the Martin furnace is empty in its greatest volume, the melted materials radiate towards the arch, and the arch, which is enamelled by fusion of slags, radiates on the melted materials; the combustion gases pass along between these two radiating surfaces and give them only a slight quantity of heat, quite maintaining their high temperature.

There are no temperatures strictly constant in a furnace whatever its shape may be. Small temperature variations may be attained, but there is never uniformity. Even with electric heating, towards which our aims should tend, there is no assurance of attaining perfection.

In the model which I executed heat comes from each side of the furnace; the bricks are of corindite, which takes no contraction up to 1,750° C., and they have not stirred for more than two years, nor is there any reason for them to deteriorate and be changed.

I have given figures for consumption of fuel which have been noted very exactly and which can be verified; if they are lower than those which have been admitted until now it is only by reason of improvements which I have brought forward and described, improvements based on scientific and technical studies. It is possible that I may soon construct furnaces of this kind in England, where I have orders, and I propose then to show the working of them to members of The Ceramic Society.

It is certain that progress is slower in the ceramic industry than in any other industries. The manufacturers are not to be blamed, but the actual state of scientific knowledge relating to ceramics. For a long time researches were not made in this department; a few years ago the establishment of ceramic laboratories had scarcely commenced, and that only in very small number. Meanwhile the questions to be examined and solved are more and more pressing. Many employers have not, under their orders, the ceramic engineers acquainted with modern studies concerning heating kilns, raw materials, etc. They have with them only simple foremen acquainted with their routine, and for whom everything great seems impossible or revolutionary. The National Pottery Council will be able to exercise a profitable influence by interesting itself in questions of technical researches and in the creation of a body of ceramic engineers who are the indispensable auxiliaries of everything great.

I would have wished to describe the practical apparatus for management and control of the tunnel kiln, but I leave these questions to another lecture, and I desire to express all my acknowledgments to The Ceramic Society for the kind reception I have received from my fellow-members.

Mr. HUBERT WICKS.

BY the death of Hubert Wicks, at the early age of 31, another promising career has been abruptly closed. After only a week's illness, he fell a victim to influenza and pneumonia on the 1st December, 1918.

His early education was acquired at the Secondary School, Malmesbury, Wilts., and he continued his studies in Art and Science at Brierley Hill and Wordsley Technical Schools, gaining many successes.

He became a Designer and later Works Chemist at the Decorative Tile Works of Messrs. Gibbons, Hinton and Coy., Brierley Hill.

Gaining a County Council Scholarship, he proceeded in 1911 to the Pottery School at Stoke-on-Trent, and there studied under Dr. J. W. Mellor until 1913, after which he returned to his work near Stourbridge, eventually becoming Works Manager. While a student at Stoke he joined The Ceramic Society, and took a lively interest in its proceedings. In 1913, jointly with Dr. Mellor, he prepared a paper on "Nickel In-Glaze Colours," which is printed in volume 13 of the TRANSACTIONS. Owing to physical disability he was unable to render military service to his country, but nevertheless took his full share in helping to "carry on" at home. He will be much missed in many circles. J.A.A.

XIV.—Notes on the Preparation of Bodies.

[THE PRESIDENT'S ADDRESS.]

By R. L. Johnson.

In contemplating the accepting of the honour The Ceramic Society offered to confer on me by electing me their President, although I had more responsibilities and undertakings than I felt I could satisfactorily discharge, I thought that possibly an affiliation or linking up to the manufacturers' organizations was desirable and ought to be beneficial to both parties.

Unfortunately for this Society in the past, pottery manufacturers have been to some extent associated to one another in various associations; these associations were not in any way connected. Some of these associations possibly may have been aware of some of the good work that was being done by this Society, and gave some financial assistance towards the Abstracts, while others, I am afraid, were not brought sufficiently in touch as to bring into their deliberations any financial assistance to The Ceramic Society.

During the past year all these associations have now federated into one federation, the British Pottery Manufacturers' Federation, and I am pleased to think that one of the first propositions of this Federation was to vote a sum of money sufficient to discharge the liabilities which had been contracted in publishing Transactions, a copy of which, on account of the increased cost of printing, etc., has cost more than the subscription for membership, even though most of the work of editing, etc., is so kindly done voluntarily.

This is a step in the right direction, but to me there seems another very important step necessary, which I hope will soon be in operation. This is the connecting up of this Society with the Research and Inventions Committee of the Federation. This committee may require some jurisdiction over The Ceramic Society: on the other hand the Research and Inventions Committee for this would naturally have to find a *quid pro quo* in assisting The Ceramic Society financially.

It was possible that The Ceramic Society could have obtained an annual subscription from the Federation, but

personally I feel that it is better for this to be fully considered by the Federation through the Research and Inventions Committee in order to try and obtain more direct interest in The Ceramic Society from manufacturers.

During the past twelve months Dr. Mellor has certainly been doing his best to get manufacturers to take more interest in this Society by having arranged two meetings. First, a joint meeting of this Society and the Staffordshire Pottery Manufacturers' Association, when a paper by Dr. Bigot was read on Tunnel Kilns, and certainly the interest, attendance and discussion at that meeting was remarkable. Second, a joint meeting of this Society and the China Manufacturers' Association, when Dr. Mellor read a paper on certain faults in connection with china bodies, which also created a good deal of interest and was largely attended.

My principal objection to accepting the office of President was that it would be necessary for me to give an address, and, as I am not an expert on any subject, this is a difficult proposition. A manufacturer of pottery has hardly the opportunity as a rule of becoming an expert, as it is necessary to be Jack-of-all-trades, for not only is each department a trade of its own, but there are so many subsidiary trades connected with the manufacture from the general building trades, engineering, etc., even to the manufacture of brass and plated goods.

It is obvious that if it were possible to produce and sell only one article on a large scale, such as one size plate, it would be possible to effect a very considerable saving in the cost of manufacture, but this is not feasible on account of firing (this may be overcome when tunnel kilns can be adopted), and also one cannot sell one size plate to make a dinner set. The principle, however, remains, and a manufacturer who limits his productions in shapes, patterns, classes of ware, etc., who in fact specializes, is enabled to concentrate his energies in producing these in the most economical and best way. This is done very successfully in this and other industries.

Quality ought to be our aim, although it is quite true there is a good demand for articles of inferior quality, but the additional cost of making good quality is not very much greater than for making inferior, and the better quality always commands an easier sale or higher price; further, and a very important point, future business is more secure, for "Quality is remembered when price is forgotten."

I have had a little experience in the comparison of cylinder *versus* pan milling of flint, and although I am unable to give

you actual figures of costs in each case I can give you some idea as they appear to me.

In the first place it is quite possible to produce equally as good finished material from cylinders as from pans, but in making comparisons of cost it is essential that the finished product in each case should be equal in every respect, and that the method of obtaining this should be the most economical in each case respectively.

Let us consider some of the main items.

Steam. The cost of a unit of steam would be the same in each case. The amount of steam used per ton of flint ground would be higher in the case of pans, not so much because pans require more power to drive them, but partly because the load with cylinders is more uniform and constant, whereas an engine for a pan mill has to be built for the maximum load at charging time, which is not so economical during the greater period of grinding, and partly because the gearing which is necessary between the engine and the actual grinding absorbs more power in the case of the pan mill.

Cylinders have a further slight advantage in that the engine can be run with equal safety at a higher speed than the engine for a pan mill. It is very difficult for actual figures to be obtained on those points, for whereas the cylinder mills generally have been built on modern economic lines, the pan mills are not so modern, in fact in this district the amount of fuel required to grind one ton of flints on a pan mill varies from 6 cwts. to 20 cwts. The liability to breakdown is considerably higher and more serious in a pan mill.

The labour and management cost under equal conditions is greater in the cylinder mill, but this is generally counterbalanced by the cylinder mills having more labour-saving appliances; but it is quite feasible for these labour-saving appliances to be worked successfully in a pan mill.

It must not be overlooked that tipping the flints as they come from the kiln on the mill floor has its advantages, for a considerable amount of dust and dirt is thus extracted which would otherwise be ground with the flint to the deterioration of the finished product.

For cylinders it is certainly preferable to crush the flints to the size of beans, but this is unnecessary for the pans, as the latter are extremely rapid crushing machines and crush without dust at practically no cost.

Capital outlay. The cylinder mill has the advantage in this respect. Personally I am quite satisfied that for milling flint in this district, when the standard is good quality and washed to a fine degree, the cost of grinding on a pan mill is not more than

the cost of obtaining the same degree of quality and fineness by washing by grinding on cylinders, the most economical methods in each case being adopted. Where the standard is less finely ground finished material which can be obtained by lawning, the cylinder methods will be the more economical, as it is practically impossible to use lawns for material ground on pans, and the increased production by lawning is very considerable, materially reducing the cost.

The first thing therefore to settle is the degree of fineness required, and then the best method of obtaining the desired result; it must not be overlooked, however, that the finer the flint the cleaner and freer from specks, and the greater its action as a refractory material.

An earthenware body and glaze, well balanced and free from crazing when using finely washed flint, will probably craze badly when made with less finely washed or lawned flint. The setting of ground flint in stock arks is in a large measure overcome by finer washing, and it is of no consequence whether the flint is ground on cylinders or pans.

Some years ago what is known as a patent press was purchased and erected in a press house containing two or three ordinary 24-chamber presses. The nature of the articles produced on this factory required clay as plastic as it could be obtained from the body mixture, and also as free from liability to cracking in the potters' shops as well as during the firing. After having overcome many of the difficulties of a patent press, the press was pronounced a success, and as the results in the clay shops and biscuit warehouse were much better than they had been for some years it was naturally assumed that the addition of the clay from the patent press had improved the clay as a whole.

On the manager over this department retiring his successor was not so smitten with the patent press, and to make sure had the clay from the two types of presses kept and pugged separately, certain operatives using only clay from the patent, the others only clay from the ordinary press. The result was soon apparent, as the operatives using the clay from the ordinary press went on as usual, but the operatives using the clay from the patent press had scarcely a piece in the clay state that was not worthless. The patent press was immediately discarded, and although the manager had produced results so satisfactory with the inclusion of the patent press how much more successful would he have been without it. His successor, an amateur by comparison in the potters' shops, was enabled to more than equal him in results by negating the disadvantages of a pronounced successful patent press.

By giving you this do not think I condemn the patent press, for there are many sliphouses where the patent press for results is equally as good as the ordinary press, in fact in the sliphouse to which I have referred in which the patent press was taken out and dispensed with, and an ordinary press fixed in its place, to-day the ordinary press has again been displaced by a patent press; but it is now not essential that the clay should have the utmost plastic properties, for after being pressed it is made into casting slip, and therefore it is only a question of the most economical method of extracting the surplus water. This again brings us to the point of first settling the properties of the material required and then the most economical and best method of obtaining the desired result.

A collection of good recipes for earthenware bodies is without doubt valuable. The chemical analysis of any body can be obtained fairly readily, and if we add the source of each material we shall probably have a recipe as complete as is usual in a list of recipes. This is, however, far from being all that is required, for in a real good body we shall probably find that when we try to put this into practice the clay is short, unless we know how to manipulate the ingredients and the body when mixed so as to procure the greatest amount of plasticity.

There are many ways in which we may tend to destroy plasticity. Let us take an earthenware body which contains a high percentage of milled material and requires all the plasticity that can readily be obtained to manufacture it successfully. One may rightly ask: "Why make such a body?" I think it will be readily admitted that to make a real good white body it is necessary to work somewhat on these lines. The higher percentage of milled materials and the finer they are ground the whiter, freer from specks and the more china-like will be the body, speaking generally.

The ball clays should be kept in as plastic a state as possible; both ball and china clays should be blunged to a thick slip, the thicker the better so long as workable, but do not overblunge. The flint and stone, to get as much plasticity as possible, ought to be washed fine and aged as much as possible in a slip state and used for mixing in the body at not less than 32 oz. to the pint. By these means the body slip when mixed will be as heavy to the pint as it is practical to obtain.

When lawning it is usual to add scraps which have been reblunged, and these should be added in a slip which is heavier to the pint than the newly mixed body. (The scraps for blunging should be kept in as plastic a state as possible, and as

few white scraps used as possible.) In this way the body slip entering the stock body ark should be heavier to the pint than is practical to obtain in a newly mixed mixing. The stock ark should have a good holding capacity in relation to the amount of clay used and should be kept as full as possible.

Press pumps should be kept in good order and placed near, vertically, the stock ark, preferably in such a position that the slip will run by gravitation to the pump. Clay presses made of wood are preferable, and the cloths good for easy filtration, and kept clean, for which cleaning it is better to use hot water. The clay press trays should be made to give a reasonably thin wad of clay and must be uniform. The clay must be pressed to a uniform degree suitable for the operatives. The presses after being filled should be allowed to remain full as long as possible so that the wad of clay may become uniform throughout, and also the clay remaining in the press increases the plasticity. On the clay being taken out of the press it is advisable to stack and cloth it up for 24 hours before pugging.

The pug should be well adjusted so as not to exert undue pressure on the clay at any particular point. There is an article in the Journal of the American Ceramic Society dealing with the air in clay before and after pugging, and giving the method of obtaining the amount of air present in which I think it would be advisable if some member would interest himself with a little study on this point.

In any of the foregoing, as well as many more points, the plasticity may be decreased, so that with a body which is only workable when practically all these items are being done to the best advantage, the inattention to two or three may mean the impracticability of working such a body. In touching on these various points I hope it will provide food for thought.

XV.—The Osmotic Purification of Clay.

Lecture by W. R. ORMANDY, D.Sc.
(Reported by H. Townsend.)

The following is a report of the public lecture delivered by Dr. Ormandy at the conclusion of the meeting of the Refractory Materials Section at Middlesbrough on May 23rd, 1919.

WHEN your very learned and even more energetic secretary honoured me two or three months ago by asking me to give this lecture I gladly accepted, because the subject is one to which I have devoted quite an appreciable portion of my working experience, and having spoken upon the same subject before I did not feel that it would involve a great deal of work. On the other hand I began to realise, as time went on, that the lecture was supposed to be a popular one, which slightly altered the nature of the proposition.

Now the subject of the osmotic purification of clay really entails a knowledge of a great many physical and chemical subjects, and had we had an ordinary, average audience, it would perhaps have been presumptuous on my part to have taken for granted that all present were aware of the molecular hypotheses, of the laws of solution, of the various questions affecting the dissociation of matter in solution, of the motions of particles in an electrical field, of colloids, and other similar things. On the other hand, you will realise that it would have been a supreme task to have given even a précis, in a public lecture of an hour, of these various aspects of physical chemistry which are involved in a consideration of the subject we are about to discuss.

It is obvious, however, that the bulk of those who are present are people who have attended the meetings of The Ceramic Society, and are consequently technically educated. With your permission, therefore, I propose to deal with you as such, leaving the more elementary aspects of the subject on one side, so that we can proceed more quickly to that portion of the subject which I hope will interest you more than an elementary exposition such as would have been rendered necessary had we had a popular audience.

The fact is very well known that when small particles are examined under the microscope, such particles being suspended in water, they exhibit a remarkable to-and-fro movement, discovered by Brown in 1820 and known as the Brownian movement. Now this movement is only observable in particles having a diameter of less than four one-thousandths of a millimetre, and the smaller the particles the more active the movement, generally speaking.

Brown observed this motion in the first place in connection with the pollen of certain flowers, and naturally he was at first inclined to think that it was some manifestation of organic life. He tried the experiment, however, with pollen of plants which had been dead for a hundred years, and got similar movements, after which he tried the experiment with finely divided inert matter, such as silica and the like, and observed that these particles also moved.

Brown carried out many ingenious experiments with the object of testing whether this movement was not ascribable to heat motion, diffusion, the action of light, or some other extraneous cause, but he was unable to prove to what the motion was due.

It is interesting to note that small crystals contained in liquid enclosures in solid quartz, which particles must have existed there for time expressed in millions of years are still actively moving. It is fairly obvious that this is some inherent faculty of the material, and not due to an extraneous cause. We shall have to deal at some length with this subject of the Brownian movement, but I wish to refer to it no further just for the moment.

It is well-known that it was an Englishman, Graham, who first pointed out that bodies contained in a liquid solution exhibited different properties when put into a semi-permeable diaphragm contained in a vessel of water. For instance, if we take a tube of parchment paper, and enclose in it a solution of salt or sugar, these will come through the parchment and be found in the water outside. On the other hand, if we put in a solution of glue mixed with salt the salt will come out and the glue remain behind. And Graham proved that this behaviour, or rather this lack of behaviour on the part of certain types of bodies was characteristic of a group which he called colloids, from the word *colla*, meaning glue, and which he rightly attributed to the particles having large molecular weight and size. The particles of glue were large, and could not get through the paper, whereas the particles of crystalline salt were smaller and able to pass through.

Now it is with these colloids that we shall have to deal to-night. But although a vast amount of work has been done on the subject of colloids in general it is only with one aspect of colloid matter that we require to deal just here, and I will therefore very briefly point out that colloids differ enormously in their behaviour. We have, for instance, such substances as gelatine, which dissolves in water and makes a comparatively clear liquid. The gelatine, however, will not diffuse through the parchment tube. We can evaporate the water off, at not too high a temperature, and we can recover dry gelatine, and that gelatine is again dissolvable, and will go again into solution; in fact, the operation can be carried out quite a number of times, and on each occasion will provide us with a reversible colloid. On the other hand, we can take the white of an egg, which is also a colloid, but if we heat it up it will coagulate, and once having coagulated it is rendered insoluble. That is an irreversible colloid.

I think perhaps at this stage I had better make a few references to the sizes of particles, in order to group the colloids, because it is with a limited section of them that we shall have to deal to-night. If we take a sample of any very finely divided material, colloidal gold for instance, with which the bulk of the experiments relating to this subject have been carried out, we can get it in various colours and particles of various sizes, the colour being dependent upon the size of the particles. More work has been done upon the determination of the size of the particles of gold than upon any other aspect of the matter, and it has been found that if a particle is less than $\cdot 1\mu$, that is, decimal one of a thousandth part of a millimetre, equal to $^1/_{250,000}$th part of an inch, such a particle will not settle but will remain in suspension. The laws of gravitation, though, of course in existence, do not make themselves evident in the case of such extremely fine particles; but if the particles are larger than that there will be a gradual separation.

Now this is just about the limit of microscopic visibility, and what we have to treat with chiefly in dealing with clays are those particles which are within the limit of such visibility. It is found that the Brownian movement on these particles of clay is greater the smaller the size of the particle, and the question arises: in what way is the Brownian movement related to the size of the particle, because this is going to have a good deal to do with the matter later on.

You are all aware that if a sample of clay is blunged with pure distilled water into a creamy slip, and this is allowed to settle, the coarser particles go down first, then a perfectly level cloud forms on the top of the water, and after that the whole

of the rest of the matter in suspension goes down very, very gradually. This principle is made use of in the elutriation of clays—the separation of the particles. But not much attention has been paid in the past to the influence of the particular sort of water that is employed. But if you carry out a little experiment, viz.: take a sample of ball clay, or china clay, of 100 grammes in quantity, and shake this up in 200 c.c.'s of distilled water, and allow this to settle; and repeat the experiment with clay taken from the same bulk, but using 200 c.c.'s of hard water, if you notice the behaviour closely you will observe that there is an appreciable difference. But if you add to the water an exceedingly small amount of alkali, equal to say 5 or 6 c.c.'s of a 10 per cent. solution of caustic soda to a kilogramme of clay, you will see that the effect is entirely different. Whereas the clay in the first case formed a perfectly even milky liquid, that is to say without the alkali, in the second case, using the alkali, you get a remarkable silky appearance, and the liquid which was comparatively thick with 100 grammes of clay and 200 c.c's of water has now become comparatively thin. If you hold a glass of the solution to the light you will see the particles in suspension travelling rapidly down the sides; you would also see a little dark-coloured matter at the bottom of the glass, and that the material at the top settled with a slowness which was remarkably more pronounced than the speed with which it settled when that small amount of alkali was not employed.

Now in dealing with gold particles, it is a well-known fact that colloidal gold immediately coagulates when you come to add very small traces of a salt, and the particles go down to the bottom very rapidly. Thus, we have two absolutely opposite effects. In the first place, the addition of a small amount of salt to a solution of gold causes the particles to come down and precipitate, whereas the addition of a small amount of alkali solution to a clay solution causes it to go thin, and the particles to remain in suspension instead of coming down. That is rather a fundamental point.

It is interesting to note that Jevons in 1869 noticed that the Brownian movement of clay particles was increased by the addition of small quantities of certain types of bodies, and diminished by the addition of certain other types of bodies. In 1895 a further discovery was made by Bliss, who found that if one took a clay suspension in distilled water, and examined it under the microscope, one observed certain Brownian movements; if one added a small trace of alkali the Brownian movements were increased; but if one added further quantities the Brownian movements were again reduced. These

discoveries remained for a time isolated and no one made use of them.

You may say that it was perfectly well-known that the addition of alkali to a clay slip caused it to go thinner, because Weber used it as a means of casting. It is true that he used it, not in mere traces but in considerable quantities. But this was to make a thick clay slip into a thinner slip, capable of carrying more mineral clay to a given bulk of water. He did not use the alkali with a view to separating the constituents. On the contrary: his idea was simply to make the whole slip fluid, so that without any alteration in character or any separation of one part from another it could be cast in a plaster mould, whilst there would also be less water to remove in order to produce a solid clay article.

It was not until Count Schwerin carried out his first experiments that any direct application was made of the fact that the addition of a small trace of alkali caused the conversion of the suspended clay, which was previously in what is known as a gel or jelly condition, into what is known as the "sol" condition, that is, a condition in which the clay particles are acting as nearly like a body in solution as an insoluble body can.

But before I come to deal in rather greater detail with the practical applications introduced by Count Schwerin it is necessary that I should refer, if only very briefly, to another class of phenomena altogether. If you take a glass vessel, and divide it into two compartments by means of a porous diaphragm, and you put in two plates, one positive and the other negative, and fill up the vessel with ordinary laboratory distilled water, and pass an electric current through, it will be found that the water will go up on the one side of the diaphragm and down on the other. This is known as endosmosis. Similarly, if we take in another vessel a battery of little capillary tubes of extreme fineness under water and use two electric plates—positive and negative—the liquid will be found to move through the tubes. The extraordinary thing is that if these capillary tubes are internally coated with sulphur, the water will move in one direction, whereas, if the sulphur is not there, the water will move in the opposite direction; that the direction of the water is not dependent upon the fact that we have a capillary tube, but on the nature of the lining of that tube. The whole of this motion is characterized under the general name of endosmosis.

Now Count Schwerin was interested in the first place in the drying of peat, and it is interesting to note how a man with a trained scientific mind, such as Count Schwerin undoubtedly

had, was led from a series of accidents to carry out work which has been, and is likely to be, of very considerable value to the community. His family estate was large, and consisted chiefly of fairly poor peat land. His relatives, along with their friends, had spent thousands of pounds in the endeavour to dry this colloidal peat by hydraulic presses, screw presses, and all sorts of heating arrangements without any successful result whatsoever.

In the course of his work as a student Count Schwerin was once endeavouring to remove certain unpleasant smelling products in albuminoid materials that had been stored for some time, and in using electrical means to this end he noticed some very peculiar results. He observed that the material seemed to gather on one of the electric poles, whereon it dried to some extent. It immediately struck him that this must be a manifestation of this endosmosis, and he wondered if it might not be applied to peat.

He immediately set to work to carry out the following experiment. He took an ordinary wooden-sided sieve with a fine brass wire gauze at the bottom, which was strengthened by a perforated iron plate or stout wire netting underneath, and this he filled with ordinary colloidal peat. And I may say that although the peat contained 95 per cent. of water in the state in which it was taken from the ground, it was of such a slimy mass that it would not pass, without considerable pressure, through a lawn of 60 meshes to the inch. A thin iron plate rested on the peat and the current passed from this plate to the lower gauze. Immediately the current was turned on there was an absolute rainfall, and in twenty minutes a layer of peat slime, four or five inches in thickness, had become converted into a firm hard substance in the form of a thin layer about half an inch in thickness, which was almost hard enough to break between the finger and the thumb. What had been happening was this: the layer of peat at the bottom was acting as though it were a series of capillary tubes or a capillary diaphragm, and under the influence of an electric current the water was being pushed through this diaphragm and being discharged from the bottom.

Count Schwerin took out patents and endeavoured to apply this process on a large experimental scale at his own home. Those experiments, I may say, were at that time not successful, for it was found that the amount of electricity required to drive out sufficient water, and to leave behind a marketable product, cost too much. But the margin was very very narrow. It was so narrow, in fact, that one of the most powerful, and certainly one of the most scientific companies in Germany, was

convinced that the thing was possible, and spent some millions of marks, putting up large plants in Switzerland, with the object of carrying out the principle as a commercial operation. They came to the conclusion at the end of eighteen months or two years that it was not then quite a business proposition.

In the course of his experiments Count Schwerin noticed on one occasion when using two vertical plates with peat paste in a vessel, that when the plate was removed, and a section was cut through the residual peat, there was a thin layer of white material on one side, then another colour, and then the peat behind; in other words, that although the peat was so homogeneous, or absolutely well mixed, there were some constituents in the peat which travelled under the electric influence faster than the others, and concentrated on the plate. This immediately suggested to him another series of experiments which should show how these materials behaved when subjected alone to the same process.

Naturally one of the first things to do was to make a slip of clay, and find out how this behaved. He found that his expectations were confirmed. Clay, when merely mixed with water and allowed to stand for a few moments to permit the dirt to get out, did collect on one of the poles, and not only so, but dried to a considerable extent, although it collected on the pole *below the surface of the water*. He took out patents for the application of this principle industrially, but he very soon discovered that though this and that particular clay might behave quite well under the process, a further clay would not behave so well, and yet another clay might refuse absolutely to collect on the pole.

Then began research work as to why some clays moved and other clays would not. There was nothing in the appearance of the clay itself to suggest a reason. It was quite impossible then, and it is to-day, from an examination of any sample of clay, either in the natural state or mixed up with water, to say whether it is going to move or not under the electric current. Eventually Count Schwerin came to the conclusion that the fact that the clay collected on the pole at all showed that it must have an electric charge. A reasonable course of action was to make use of the experiments of Bliss, viz.: to put in a small amount of alkali and see what happened. With these conditions he found that the clays which previously would not move now moved. This led to a further series of experiments.

These further experiments showed that there were clays which, even with the addition of alkali, would not move at all. The necessity arose of finding out some means of getting over

this difficulty. Being aware of the fact that clays are rendered more plastic by the presence of organic matter, and that it was common knowledge at that time in Germany that a somewhat meagre clay could be converted into a workable clay by pugging it up along with organic colloidal substances, Count Schwerin resolved to try a similar experiment. He found, as a result, that the little particles which were in themselves incapable of picking up the electrically charged medium were, however, capable of picking up the organic colloidal matter, and covering themselves with a thin layer of this matter, the additional colloid being itself capable of picking up the charged body. These particles behaved quite normally, though the original clay was incapable of motion, and the difficulty was solved.

The next point to consider was the practical application. Suppose you have a wooden trough, fitted with a lining of wire gauze, and a metallic drum which rotates slowly in the trough. At any point clay and water can be fed in, to which has been added a small amount of alkali. An overflow is provided through which the impoverished slip can be discharged. The gauze is connected to one electric pole, and the drum to another, and an electric current is set in motion. A thin deposit of clay commences to form on the drum, and gets thicker and thicker, and although this is deposited on the drum actually *under the water* the clay is found to come off drier than one could dry it by the use of an ordinary filter press if one were to use a pressure of 150 lbs. to the square inch for any length of time. In other words, a ball clay which you cannot bring down to 40–45 per cent. in an ordinary filterpress in any reasonable length of time—if ever—will come off this machine which I have been describing with $17\frac{1}{2}$ to 18 per cent. of water, in so dry a condition that it cannot be pugged, actually breaking off into slabs as though it had been dried in an oven.

The cause of the dryness is this: the clay particles which are near the electric pole come on to its surface owing to their electric charge and form a very thin layer or skin. This skin, owing to the fact that it is made up of a number of very small particles, is nothing more nor less than a series of capillary tubes, and instantly the water is sent away. The clay particles that have to go forward have to travel through a counter-current of water which is being pushed out at quite a considerable velocity. It is certainly a very interesting experiment to carry out to notice how, in spite of the fact that the stream of water is pushing away from the anode the clay particles are attracted with a power that is so great that they are at the same time dried.

A previous lecture which I gave before the Society was accompanied by a series of photographs showing certain samples of osmotically treated clays, and I thought it might interest this audience to have the actual samples of clays from which these photographs were taken. The photographs were not quite accurate as regards colour values, but you will be able to realise from these samples that, generally speaking, the photographs were fairly representative of the samples.

We now come to the point: how does this particular treatment lead to the purification of clay. Well, it has been found that most bodies when placed in water take on a negative charge of electricity. Nearly all clay particles are negatively charged. Silica takes on a very much less intense charge than clay, and some bodies such as iron hydroxide take on a positive charge. We may, generally speaking, say that pyrites and iron oxide are positive, whilst silica is practically neutral, and clay electro-negative. Now supposing we have here an electro-positive particle, here a neutral particle and there an electro-negative one. If a substance of negative nature is put into into the solution it will neutralise the positively charged particle, and if it is adsorbed by the electro-negative particle it will increase the charge already existing.

It has been found with a suspension of iron hydroxide that if you add a very small quantity of a suitable electrolyte you can coagulate it, because it has been found that when a colloidal particle has its charge neutralised it begins to attach itself to the next particle which has got its charge neutralised. Therefore, by adding the right amount of alkali you can cause one lot of particles to be neutralised whilst the others are more excited. This is one means whereby this process can cause a separation which would not be possible without it. Because, if the iron hydroxide particle is as small as another, they are both going to settle out in the same length of time. If you employ a Gee separator and whizz them up you are simply going to accelerate the action of gravity, and you cannot separate, by any system of elutriation, particles which are of equal gravity and equal size. But, if you add something to the suspension which will increase the electrical charge on one lot of particles and will neutralise the charge on the others then the articles which have no electric charge will immediately show a new set of properties.

It is clear that if you have a number of particles, positively charged, moving about at great velocity in water they may get close to one another but still repel each other. There is no tendency for them to stick together. On the other hand, if we have a particle that is positively charged and another

that is negatively charged, and the two collide, there is no longer a charge at all, and there is no reason why they should not stick.

Now around every particle in water there is probably a little sphere of water, but if the attraction of this water particle for that is greater than for the material underneath it they will combine, and the particles become one. By the addition of a small amount of alkali you cause certain particles to accumulate into a smaller number of a larger size, and these settle out rapidly. This is a crude explanation of how the addition of traces of alkali can be made to assist in the process of electric purification. It is simply a question of taking advantage of those isolated facts which have been known for years, but of which, until recently, no-one has seen the practical bearing.

There is another reason why this process leads to purification, and it is so obvious that I need not waste much time upon it. If we take a hundred grammes of china clay and a hundred grammes of water we get a thick, heavy, almost creamy slip, consisting of comparatively large particles of clay, and the dirt, pyrites, silica and sand cannot find a clear way through. As these big sticky particles of clay come down, each having no electrical charge, they have a tendency to stick on to other things, and come down with the impurities, and although you have some separation in the tube you get thick pasty matter at the bottom, and a thinner material above, but the matter at the bottom contains a large amount of clay. In order to get the separation in the tubes you would require to do what they do in the china clay mine, use three tons of clay to 97 tons of water, and make a slip so thin that the mica and the sand have a chance of separating out. But I can imagine what some of the fireclay manufacturers would say if you suggested to them that if they wanted to make three tons of fireclay they must mix it with 97 tons of water, run it over a drag, allow the impurities to come out, and then collect the clay, and it is not the sort of thing I would like to say before an audience.

You may be interested to know how the operation of dealing with the clay on a work's scale by this process would be carried out. The clay is dug out of the ground in the ordinary way, put into a blunger, and mixed in the blunger preferably with the necessary amount of either alkali or alkali-colloid, which has been proved by laboratory experiments to be the quantity necessary in order to give just the amount of electricity (to put it in a very crude way) to neutralise one set of particles and electrify the other lot of particles, and by so doing cause the material to take on the "sol" state, so that it is thin, and the impurities may settle out rapidly. You may

find that it is necessary to add 6 c.c. of a 10 per cent. solution of caustic soda to a kilogramme of clay, and experience may prove that it is advisable with that particular clay to use 1½ kilogrammes of water. The mixture then runs from the blunger into a settling tank. What is going to happen there is very largely under control. You may decide in the first settlement to permit only the very coarsest particles to settle. You may get out at this stage fairly big particles of pyrites and coarse sand, but you will certainly get no appreciable amount of clay. The settlement can be continued five, ten, fifteen or twenty minutes, or possibly half-an-hour. You then run the clay from the surface into a second tank, where you may allow a longer settlement. It depends entirely whether your object is to get a clay substance free from fine—the very finest—silica and impurities, which can be separated by settlement, or whether your object is to get as large a bulk of clay as possible, free from just the coarser impurities which settle out rapidly. That will be entirely a question of markets.

In the case of certain clays in the Potteries, for example, where the amount of clay substance present is only about 50 per cent., it proved preferable to settle first for five minutes, which enabled a very large quantity of pyrites from all sizes as big as the thumb down to a fine powder, as well as the coarser sand, to settle. A second settlement was allowed of about half-an-hour, and this permitted the settlement of fine and medium sand with very little pyrites and very little clay, which material proved to be quite good grog for use along with the clay employed for the manufacture of certain cheaper articles, such as saggars and the like.

Having purified the clay slip to whatever extent is required by means of settlement, it is run through the osmose machine, where a further undoubted settlement takes place.

At Schoelen, in the east of Germany, there were three osmose machines running on very plastic ball clay deposits which had been used previously, with the admixture of other things, for the manufacture of drain-pipes. The clay was so full of pyrites that it had been quite impossible to use it for any other pottery purposes. After the installation of the osmose machines it was found that the sale of the pyrites from the settling tanks was a very appreciable asset. It was shown that the iron pyrites was present in particles from the size of one's fist down to an impalpable powder, and the pyrites actually constituted 10 per cent. of the sales. It was not a clay mine, but a pyrites mine with clay in it.

After the material had been allowed to settle, and this did not take very long, the top slip was run through the osmose

machine at such a rate that quite a considerable amount—ten per cent. of the total amount of the clay—was allowed to pass out with the discharge. This ran through the settlement tank for an hour, and the supernatent liquor was pumped up and used to blunge the second lot of clay, so that the clay which was missed in the first operation was caught the second time round But at the bottom there accumulated an exceedingly fine velvety powder—extremely fine pyrites, as fine as the clay itself. This had been rejected in the osmose machine.

The practical application of the laws which we have been discussing to-night will have a bearing upon the whole future of the clay and other industries.

It may interest you to know how I became connected with the osmosis process. About nine years ago Dr. Markel, then technical director of Messrs. Joseph Crosfield & Sons, Ltd., showed me two sample slips of treated and untreated clay, and informed me that these represented the results of purification by a new electrical process then being developed in Germany. I was sceptical as to the economic practicability of any such treatment but decided, on the information given me, that it was worth going to Germany to look into the matter. I went to Frankfurt, and in the absence of the inventor (Count Schwerin) was directed to their English agent. On returning to London I found that the London Agent was more commercial than technical, and I arranged to visit Frankfurt a second time to meet Count Schwerin, who died comparatively recently. Count Schwerin was not only a great scientist but a great gentleman. During the three months he not only gave me the fullest information in his own laboratory but took me to look at their existing plants in various parts of Germany. After some months study of the process and its possibilities I decided to return to England to form a small company to test English clays, and if possible to acquire the English rights for the process. Such a syndicate was formed, and in all some thousands of pounds were spent in testing and reporting upon nearly 100 English clays. At the end of two years' work it became obvious that the English clay producers were not sufficiently interested to take the matter up. They were accustomed to digging clay out of the ground and selling it or using it without treatment, and showed no signs of any desire to adopt more modern methods. Just prior to the outbreak of the war the German company decided that the only way to introduce the process in this country was to acquire clay properties, and if necessary to start in the manufacture of refractories. Undoubtedly nothing but the advent of the war prevented this policy being carried through.

Some 18 months' ago the Optical Department of the Ministry of Munitions required certain refractory articles having an exceedingly high melting point combined with other special requirements, and Mr. Highfield and I were able to supply them with raw material produced on an experimental scale which met these requirements. This led to the formation of the present Osmosis Company.

It was probable that nothing would have been done with these patents by the clay industry, as although the patents themselves were masterly technical documents they necessitated a great deal of experimental working being done before any practical results could arise. It is true that a patent to be valid must be so drawn that one skilled in the art can use it. The fact remains that the clay workers were not skilled in the art involved in the application of these new physico-chemical laws. Even with the considerable knowledge of the process I had acquired in three years' work and many visits to Germany as a basis to work upon it was found that a great amount of work had to be done to put matters on a commercial footing. I am pleased to say that the work of the Osmosis Company has resulted in the development of an osmosis machine which seems to be a considerable advance upon the last German machine which I saw, and certainly our theoretical knowledge of fundamental principles is greatly increased.

You may be interested to learn something of the effects of the osmosis treatment upon the clay. The product which is separated by the treatment is recovered in a comparatively dry state, it has always an increased plasticity, it sinters at a temperature which may be anything up to 300° C. lower than that of the original clay, it shows a greater contraction and has always a higher melting point. It is not necessary for me to point out to this audience what these new properties involve. Undoubtedly such products have a great range of utility, and there is no doubt that the pottery people as well as the glass-house people will discover that there is more than mere theory in the application of these comparatively abstruse laws to the principles and practice of everyday life and work.

XVI.—Nigerian Pottery.[1]

By D. Roberts.

Mr. Emery (before the paper was read):—I have been asked to make a few general remarks on native pottery before reading Mr. Roberts's paper. The standard of civilization reached by any nation is reflected in its style or type of pottery; hence a study of national pottery is of great value historically. It is also important from a technical point of view, since each nation has brought to a high degree of excellence some pottery method or process peculiar to itself.

There are numerous cases in which some old type of pottery has not been overshadowed by modern productions despite long and careful research. Persian turquoise and Grecian black glazes, Samian ware, and certain varieties of Oriental porcelain are notable instances. Last year some of our keenest members were surprised at the excellence of the coffee pots made by Sudanese potters. The Ceramic Society represents the highest technical skill attained in contemporary pottery, the lectures and discussions are mainly concerned with the latest scientific and industrial developments in ceramics, but even a Society like ours might do well to review ancient pottery manufacture and endeavour to discover some useful ideas which could be adapted to present needs.

The collection of "Nigerian" pottery lent by Mr. Roberts is very instructive, including as it does specimens of purely native origin, as well as others made under his supervision.

Mr. Roberts:—Dr. Mellor having requested me to write a paper on this subject, I have pleasure in giving you an outline of my experiences among the native potters, during my eight years' tour in West Africa as pottery instructor.

It would perhaps be less difficult and more entertaining to trace the history and progress of a trade which has developed for ages than to write an account of one which remains almost as primitive to-day as it was in the beginning. Still, the

1 We are indebted to the Proprietors of *The Pottery Gazette* for the loan of the blocks illustrating this paper.—Ed.

Fig. 1.

student of pottery is always interested in anything that pertains to his trade, and if you were to show him a piece of beautifully finished china and a piece of crude native pottery, he would clasp the former and still have a desire to possess the primitive article, and so my account, although unadorned and simple, will, I hope, be of interest to him.

During the past twenty years education has made most wonderful progress in all our West African Colonies and technical instruction has been well attended to. Among other trades it was decided to give the native potters an insight into European methods, and in 1905 I was appointed to go out and give them the necessary instruction.

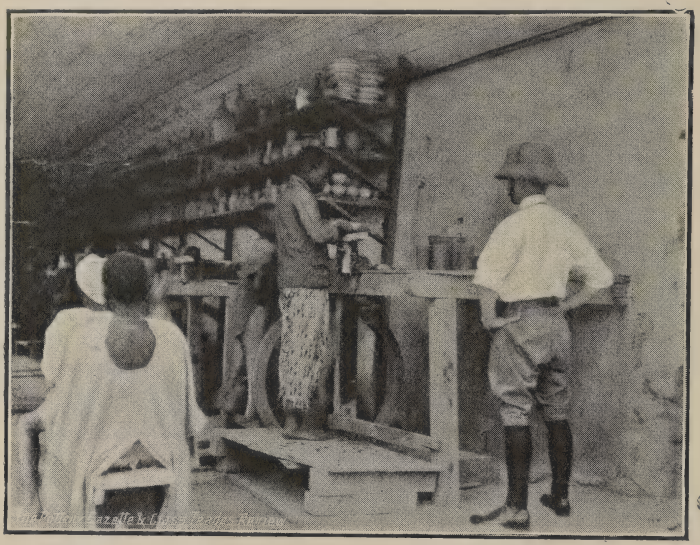


Fig. 2.

We read of the potter's wheel and spinning cone in existence long before our Christian era, but even these in their crudest form have either been lost or were never known amongst the natives of West Africa, although almost every town has its potters. In some of the larger towns that I visited there were as many as twenty pottery compounds, most of them with say fifty workers, mainly females, the menfolk being away on the farms. In Fig. 1 you will see a small but typical native pottery which was near to my headquarters at Ibadam, Southern Nigeria, just across a small stream from where I built my first potter's shed, shown on Figs. 2 and 3.

For clay, the stratum three to four feet beneath the fee or top soil is dug out in small pockets, never more than eight or nine feet deep and about twelve feet in diameter. The clay is heavily charged with mica sand, which serves the native potter's purpose very well in keeping the ware open for quick firing and cooling. On examining the cover of the sacrificing-pot you will see the micaceous particles glistening with a golden lustre.

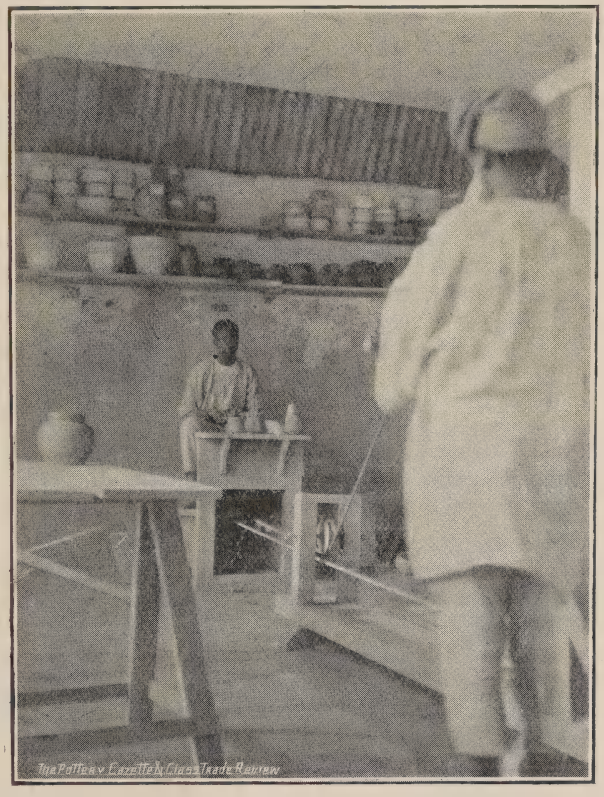


Fig. 3.

The only process to which the clay is subjected is a good "mauling," and to the right of Fig. 1 you will see a girl working the clay with a double-ended "maul."

For shaping, an open vegetable gourd or calabash is selected according to the size of pot required and the purpose for which it is intended. To make the bottom part, a piece of clay is batted on and then allowed to dry until the next

day, when it is turned up and the top part built to completion, whether for a large water pot or a deep soup plate. This is done from a roll of clay, and in Fig. 1 you will see to the left the bottom part of a pot which has been placed on a piece of an old pot in order to preserve its shape; the woman in the foreground with the roll of clay in her hand is completing a similar vessel.

There is no attempt at colour embellishment except in Dahomey, where a red and white gamboge is applied and dried in the sun; but the native who likes to see his pots look "fancy" uses incisions made with a sharp stone or a wooden peg, and if he wishes to roughen his ware and give it the appearance of honeycomb pattern, he does so with a piece of tightly twisted whipcord which, rolled on the pot while soft, acts as his turner's runner. If lines are wanted, the maker sweeps round backwards for each incised line, and, as there are often half-a-dozen lines on a pot, the worker goes about six yards to put on as many lines. In a very large compound in Oyo, I constructed for the potters a saggarmaker's whirler and showed them how much quicker and easier it was to make the incised lines on a revolving pot than to move one's body round the pot. The natives expressed their gratitude and clapped their hands with delight, but when I visited this compound again on my return journey I found the whirler discarded and the workers doing their encircling movements as before.

The firing is done in the open. A mound of clay pots intermixed with dried leaves, faggots, wood, corn-cobs, etc., is made, which looks like a turnip hog. It is lighted at about 4 a.m., and is burnt off in about 12 hours, thus giving from 4-30 to 6 o'clock to cool. Then the pots are taken from the hot mounds by means of poles, and a fine scrambling time it is to get them in the sheds before dark at 6-30 p.m. Those pots which are intended for cooking purposes are dressed while still hot with a liquid preparation made from resinous leaves, this treatment makes them fairly watertight by sealing the pores of the ware. This ends the description of the most primitive methods of potting imaginable in the 20th Century.

The articles made are water pots, cooking pots, deep plates, native lamps, water-coolers, pots for religious and thanksgiving ceremonies and articles for almost every purpose except household decoration, which were precluded owing to tribal warfare and other circumstances before these countries were taken under British control. Since that time European goods have filled this need.

The wares are sold in the open markets of the principal West Coast towns just as in our own country. There are

certain special pot-fairs held each year, and every market has its pottery section with a "Mother of the Market" or "Eye Loda," who fixes the prices, thus preventing any undue competition. To aid this matter each pottery has certain goods allocated to it for making, and if the rules are not observed the makers are not allowed to take the goods to the market.

Native living is cheap; 1,000 cowries or shells represent threepence in value. Two lamps are sold for five cowries, medium-sized pots cost about 300 cowries, whilst those as large as a "Derbyshire" bread stein would be sold for 1,000 cowries. The four-handled vase and the "Benin" native pipe exhibited this evening each cost me one penny, but of course the natives always charge white men as much as they possibly can. A native labourer's wages up country is sixpence, and he can live extremely well on twopence a day, thus, though the price of pottery is low, you must remember that everything else is in proportion.

There is plenty of latent ability among the natives, and the large sacrificing-pot exhibited was made at a farm pottery scores of miles from a town and hundreds of miles from the nearest school, so that no European idea could have been imparted, and whatever art there is in the piece originated in the brain of a black woman. Some of the pots are used in making thank-offerings, perhaps to "The Spirit of the River" for a bountiful supply of water in the rainy season, or the "Olu" or God for the gift of a child, others may be placed beside a footpath or on a sacred hill, according to the local tradition. The pots are beautified according to the use to which they are to be put.

Owing to the coarseness of the body and the shortness of the fire the durability of native pottery is very poor. The natives are quick to imitate, and they made rapid progress even when I could teach them only by signs.

The clay in use in Nigeria at the time of my arrival was useless for throwing and turning, so I had first of all to prospect and find a suitable one, generally from indications on the nearest river banks, sometimes from information supplied by the older chiefs. Having found the clay, there was the building of a suitable shed, kilns, etc., to be attended to. In one shed I set up a filter press. At this primitive pottery works were produced the first thrown and turned, cast and pressed goods, glaze finished, ever made in West Africa.

The specimens of glaze-finished ware on the table were made under the greatest difficulties by native boys and girls. We had no bricks, so the kilns had to be built of mud in the dry season. Even then some unseasonable tornado would

destroy the structure before it had time to set properly. Fig. 4 gives a good idea of the appearance of the kiln. Fig. 5 shows the ware immediately after drawing from the

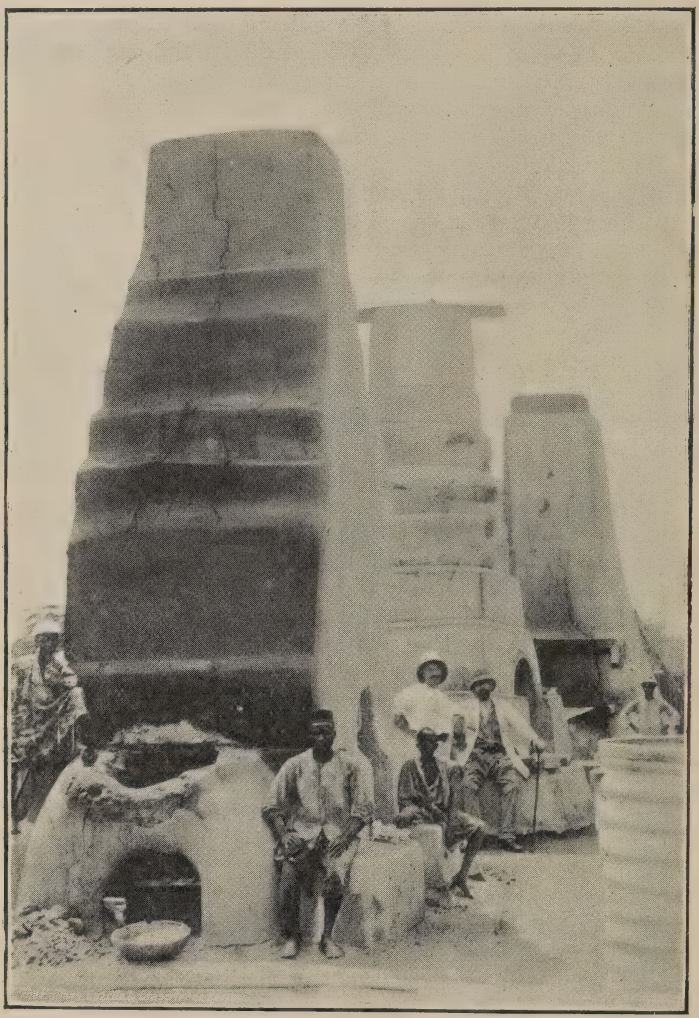


Fig. 4.

oven. If I were to relate all the details of instruction required by these young potters, from teaching weights and measures to splicing ropes, it would weary you.

At the time of my first visit to West Africa, European pottery was only to be seen in the coast towns, and then only in very limited quantity.

Railways were few. In Sierra Leone there was a single line some 40 miles long; in the Gold Coast a single line to Tarquah, 40 miles; and in Nigeria to Abeoquta 60 miles. But in the last decade railway construction has proceeded apace,

Fig. 5.

and as a consequence European pottery is being transported into these regions in ever-increasing quantity.

The population of the West Coast is much greater than is generally supposed. From Sierra Leone to Nigeria and the Hinterland there must be quite 100,000,000. The country is teeming with natural wealth which is only just being tapped; the natives have plenty of money and are greatly disposed to

trade. One of their greatest needs next to cloth is pottery, and although the amount of ware supplied from Europe is at present comparatively small, the outlook for the future development of this great market is very encouraging.

In conclusion, I might mention that the natives showed the greatest interest in our work at the various centres. Some of the chiefs travelled hundreds of miles to see the boys at work, and they did not leave until they had watched the ware go into the kiln and come out glazed, when they would purchase all the pots for distribution among their tribe. The visiting chiefs constantly invited us to set up potteries in their territories.

Perhaps it may interest you to read some of the remarks in the visitor's book kept at one of the pottery sheds, and I lend it for your perusal.

Mr. EMERY (at conclusion of paper):—I think we all appreciate the value of Mr. Roberts's pioneer work. Native races resent the introduction of modern methods, yet the author went to Nigeria, imparted modern ideas and succeeded in training some of the natives to become, at least, semi-skilled potters. Personally, I believe that less skill is necessary to make pottery in our own district, where we have at hand every mechanical appliance, and where manipulative ability is intensified by successive generations of craftsmen, than is required for the manufacture of pottery under conditions such as those described by Mr. Roberts. To be a successful pottery instructor a man needs to be a potter in the widest sense of the word. He needs courage to undertake the task; he must have practical knowledge and ability to impart it to others, the necessary technical training to apply fundamental principles and to adapt them to the treatment of unknown materials; finally, he must be a leader of men. I am glad to know that we have latent talent in this district which, given the opportunity, asserts itself successfully in this direction.

DISCUSSION.

Mr. J. A. AUDLEY:—We are much indebted to Mr. Roberts for the paper which has just been read, and to Mr. Emery for the interesting way in which he has put it before us. It has occurred to me, in connection with the announcement made early in the evening of the projected visit to America, that if only one could work on a big scale, there would be a grand opportunity for those who advocate the heuristic system of teaching to begin in West Africa with the most primitive

methods that one could expect to get, and, when these have been inspected, to step across to the Soudan and see what is being done there. It would be an easy transition to Egypt to see what the modern Egyptians are capable of, and then, coming across the Mediterranean, one could give a passing glance at places like Greece, and some of the more remote parts of Italy and Spain. A big trip across the Atlantic would then enable one to have a view of American ideas in pottery manufacture. One might then return and see the more advanced European nations, France in particular. Finally, one could come back and finish up in our own district, where I think we can claim to be as advanced as anyone else as regards potting methods and artistic productions. I have left out the far Eastern potteries, because they are of a different type altogether.

What we have heard to-night certainly takes us back to the very beginning, and it is always interesting to dabble in the early stages in the progress of any industry. It enables us to realise, much better than we do under ordinary conditions, the advantages of civilization, and the power which is given to us by knowledge. I was informed shortly before this meeting commenced, of a little incident that occurred in Mr. Roberts's experience in connection with the filter press that was taken over from England. When it was landed it appears there was a difficulty in completing the final stage of the transport, and after some trouble Mr. Roberts borrowed a rather primitive sort of truck to hold it, which, although heavy and cumbersome in appearance, was adapted to the country and the nature of the ground over which it would have to travel. The niggers that Mr. Roberts had with him would not attempt to carry the press without some such arrangement. At last he managed to get the press nicely fixed on the truck, and left them to bring it along. Some little time afterwards his attention was called to a commotion that was going on, and he went out to see what was happening to the press. The niggers had brought it along all right, but they had carried both the truck and the press on their heads. That was the best idea they had of the way to transport an article of that kind. Since then they may, perhaps, have learnt a better method, but, as you have heard in the paper, they do not seem to hold tenaciously to new ideas. There was that case of the whirler, for instance; they approved the idea in the first instance, and yet somehow or other when Mr. Roberts left them for a while they got tired of it, and reverted to their old, primitive ideas. All this is very entertaining, and the results that we are able to see on the table give us an idea of the progress that has been made,

especially in regard to the glazing of the pieces, under disadvantageous circumstances. I think there can be no doubt that with reasonable encouragement the native potters of West Africa should make much greater advances.

I have much pleasure in proposing a vote of thanks to Mr. Roberts for his paper, which Mr. Emery has so admirably set out.

Mr. F. TURNER:—I have very much pleasure in seconding the vote of thanks so ably proposed by Mr. Audley. Whilst Mr. Audley was speaking I could not help thinking that we should all very much like to take advantage of his itinerary. I wonder whether we could possibly manage it. Unfortunately I am afraid we cannot do it in the body, but with such papers as we have had to-night we can certainly do it in our minds. It is quite a relief to listen to a paper like that of Mr. Roberts. We are taken for a while out of the griminess of the Potteries and transported to that very interesting West Coast of Africa. I think it is a wonderful help to realise at times the world-wide application of pottery. Sometimes, I think, we forget the spirit of pottery. We are here to make money, if we can; but there are, of course, other things behind an industry than that. There is the industry itself, and the pottery industry is something to be enthusiastic about and to be proud of. The possibilities of the industry, its world-wide application, its ancient history. All these should be tremendous incentives to us, and should do us good, make us proud of our industry, and relieve our minds a little from the ordinary everyday considerations of profit and loss, and help us in that way to get better results than we might otherwise do. For that purpose alone I think that papers such as we have had to-night can be wonderfully helpful to us. When we realise what the native tribes are doing, working under such great disadvantages as they have to encounter, and we look around and see the great advantages which are ours, and what has preceded to give us those advantages, it causes us to think what a little we are doing compared to them. All these things, I think, can spur us on to take a deeper type of interest in our industry than the mere idea of making money, an interest which, in a way, should help us to make more money, by causing us to tackle problems in a different sort of way. I think the way in which Mr. Roberts tackled some of these problems in West Africa was really wonderful. The results which he was able to attain with such labour and materials as he had, entitle him to great credit and to our admiration.

I have the greatest pleasure in seconding the vote of thanks to Mr. Roberts, in which I include, of course, the admirable reading and explanations of Mr. Emery.

Mr A. C. HARRISON:—I should like, if I may, to say a word or two in support of this resolution, partly because, during the time Mr. Roberts was out in Nigeria, I was in pretty close touch with him, and had a good deal to do in enabling him to get the materials and the machinery that were used in the pottery out there. Mr Roberts came over to this country from time to time to make arrangements for the things he required, and I knew pretty well what was going on. I often felt admiration at the work that Mr. Roberts—just a single white man, absolutely alone amongst the natives—was able to do. He had to go there and try to pick up a little of their language, and help them to pick up a bit of his; and that he should have been able to carry out this work of establishing a pottery on something like modern lines was, I think, remarkable. I do not think that many men would have been able to successfully tackle so difficult a problem. It is rather sad, that in so many cases, when European ideas are taken out to the natives, unless they have a European with them constantly to inspire them and keep them going, they are rather prone to let the whole thing drop, and although I do not speak from positive certainty, my impression is, that if you were to go out to Abeoquta to-day you would find that neither the filter press nor much of this very much improved pottery that Mr. Roberts taught the natives to make would be still in evidence. I do not know whether Mr. Roberts intends to go out there again, and get them restarted. But in any case it was a most interesting experiment, and we all admire Mr. Roberts for what he did there.

Dr. J. W. MELLOR:—I would like to add my little quota of praise to Mr Roberts. Reading between the lines I am quite sure that he fully deserves all the credit which has been given to him. I am only sorry that Mr. Roberts is not himself here, because I feel sure we should have got more out of him during the discussion than the good material which he has given us in the form of his paper. I am sure that he will pardon my confessing that I do not admire the Europeanized native work as I ought to. From what I have seen of natives, I should say that in the attempt to Europeanize native taste you can easily spoil it. I know, of course, that my ideas are often totally wrong from some artistic points of view.

I could not help thinking when Mr. Roberts's paper was being read to us of the case of Pere d'Entrecolles, the old Jesuit missionary in China, about the time that porcelain was first appearing in Europe, and the letters which he wrote to Europe describing the Chinese methods of manufacture. Those letters were masterpieces in the description of pottery processes. Of course, the old Jesuit missioner was a skilled and trained expositor. The Chinese held their processes rather secret, and were not ready to divulge them. They even told many untruths to visitors, as one can easily see by reading past literature, but the old Jesuit missioner won his way into their hearts and they appear to have given him almost a free run over the whole district. None but a very sympathetic man could have so won his way with the ultra-conservative Chinese, and somehow it seems that Mr. Roberts, in dealing with the Nigerian natives, must have possessed a like winsomeness, for he too seems to have won his way into the hearts of the natives and enabled him to get along with them much better than would have been possible by other men with a different temperament. I feel that it is a very marked testimonial to Mr. Roberts that he has been able to put before us such an interesting paper describing his work in Nigeria.

Mr. A. LEESE:—Can Mr. Emery tell us whether the natives have themselves modelled those figures which are on the table? One of the first things which struck me in looking at these pieces was the modelling, and if the natives themselves have modelled these figures, crude as they are, there is no doubt that the Nigerian natives have a lot of latent ability among them.

Mr. W. EMERY:—The pottery figures mentioned by Mr. Leese are the work of a native woman living hundreds of miles away from the school. Exhibitions are held annually at Lagos, and at one of these a native boy exhibited a group showing a hen sitting on a nest of eggs, which Mr. Roberts has told me could not have been executed better by a trained pottery artist.

The native pottery on view to-night is worthy of close attention, the four-handled vase and the large figure are particularly good; the metallic effect is obtained by painting the objects over with an organic mixture composed of various resins and oils.

The quaint brass ornaments are also native production, one interesting fact about them is that they are made from empty cartridge cases left during the last "Ashanti" war.

Mr. D. ROBERTS:—I am most sorry that I was unable to be present at the meeting when my paper on "Nigerian Pottery" was read, and my thanks are due to Mr. Emery for so kindly reading it in my absence.

To Mr. Audley for proposing and Mr. Turner for seconding a vote of thanks to me, and to Mr. Harrison and Dr. Mellor for supporting it, I am greatly obliged, and to each of them and Mr. Emery all our thanks are due for the very interesting and instructive observations on the somewhat incomplete paper and exhibits I was able to prepare.

Had I realised, when in Africa, that such a paper would be acceptable, I would have provided fuller materials for it and brought away with me specimens of the clays, the implements used and the various pottery wares made by the natives.

It is unlikely that I shall go out to Nigeria again to take up similar work, but possibly in time some other pottery man may be appointed to do so, and I would suggest that he bring away with him comprehensive specimens which might form a nucleus of a local museum of original native pottery from the different countries of the world.

XVII.—Practical Guide for Manufacturers of Silica Products.

By Dr. A. BIGOT.
(Translated by J. A. A.)

Preface.

BEFORE the war the silica industry was little developed in France; the bulk of these products came from foreign parts and especially from Germany. During the war, several French manufacturers have established factories for silica products, and soon will be in a position to satisfy the needs of French metallurgy.

But since geographical conditions have often necessitated the employment of various types of siliceous rocks which have proved troublesome, manufacturers have found the need of precise indications concerning the rocks which are suitable for the manufacture and those which should be rejected.

We have undertaken a series of experiments on different varieties of silica rock; the results obtained were described in 1918 at the Sheffield and Swansea meetings of the Refractory Materials Section of the Ceramic Society, and in "Chimie et Industrie" (vol. I, No. 7). Since that time these experiments have been continued, and we proceed to explain them briefly.

Silica products, placed in the arch of Siemens-Martin furnaces, are submitted on one of their faces to temperatures which can reach 1,700° C., and this face is exposed to dusts of materials which are poured into the furnace and to splashes of slag in fusion at the moment of charging during the operation. These dusts impregnate the brick, forming with the elements of the brick new compounds which ascend into the brick because of its porosity, corrode it by degrees, and cause it to wear towards the bottom.

Under the action of the high temperature, the part of the brick which is exposed to the fire increases in volume, the volume of the other part does not change; it is necessary that this change of volume shall not cause fracture of the brick; at the same time that the volume increases, the bricks are mutually compressed and it is indispensable that they should be able to resist this compression without being crushed.

Siliceous rocks and silica products should have the following properties:

1. Resistance to a temperature of 1,700° C. without melting.
2. Resistance to crushing at high temperature.
3. Slight increase of volume at high temperature.
4. Porosity as low as possible.

Siliceous rocks are met with in Nature as two principal varieties: Quartz and chalk flint. With quartz are connected quartzites, banded flint, sandstone, millstone, etc. With flint may be connected chalcedony, which is very abundant in Poitou.

The absolute density of quartz, quartzite, banded flint, etc., varies from 2·65 to 2·66; when they are heated to 1,710° C. they increase in volume and their absolute density falls to 2·32 to 2·33; with prolonged action of the high temperature and also in presence of a small quantity of foreign matter such as lime, quartz, quartzites, etc., are transformed into material of different crystalline form called tridymite, the density of which is equal to 2·32 and 2·33, and into cristobalite, the absolute density of which is 2·31 and 2·32. After fusion the density of siliceous rocks is 2·22.

Chalk flint has an absolute density of 2·61; after heating to 1,710° C. its density becomes 2·22, and it keeps the same density after fusion. Chalcedony after heating to 1,710° C. has a density varying between 2·29 and 2·31. When pure rock crystal is heated it becomes opaque and falls into powder; transparent fused quartz, made from hyaline quartz (pure rock crystal), carried to 1,450° C., and kept at that temperature for four hours falls completely into powder. Fused quartz, manufactured with Fontainebleau sand, which is slightly impure silica, resists heat better; but if it be kept at 1,650° C. for a few hours it gradually falls to powder. Natural rocks behave in an analogous manner. Fairly pure quartz, white or grey sandstone, banded flint, etc., fall into powder spontaneously under the action of high temperature.

Chalk flint, chalcedony, heated to 1,710° C. remain compact; but if the action of the heat be prolonged for several days, even at 1,500° C., these rocks fall to powder.

Quartzites, ferruginous sandstones and aluminous rocks heated to 1,710° C. remain compact; it is the same with fused quartzite; if they are afterwards heated for several days at 1,500° C. they remain solid and do not fall into powder.

Siliceous rocks, then, can be arranged in two categories: those which remain compact after prolonged heating, and those which become friable at high temperatures. This latter category is not suitable for the manufacture of silica products

because their siliceous elements, becoming friable, lose their crushing strength and are too porous.

We have demonstrated that quartzites which remain compact, after heating at high temperature, are formed of small crystals of quartz covered with a small quantity of clay, and we have given a method for determining this quantity of clay; the clay keeps the silica crystals united and prevents them from separating at high temperature. Clay plays yet another part; in mixing with the fine parts of silica and lime, which serve as agglomerant, they form an alumino-silicate of lime, which is more fusible than silica, and which gives to burned bricks their crushing strength when cold. This quantity of clay should not be too considerable, otherwise the manufactured products easily soften at high temperature.

We have studied a certain number of ferruginous sandstones containing from 3 to 8 per cent. of iron oxide. After burning at 1,710° C. dark brown products were obtained, remaining compact even at the end of several days heating at high temperature. In spite of their colour, these rocks are suitable, like quartzites, for the manufacture of silica products. Until to-day no French manufacturer has employed them in the manufacture of silica products.

A certain number of manufacturers use quartz or flint in their silica products; on coming out of the factory kiln, after burning at 1,400°—1,450° C., these products remain compact and resisting, because the temperature has neither been prolonged sufficiently nor high enough to provoke disintegration of the silica grains; but in metallurgical furnaces this phenomenon is produced more or less rapidly and the products have only a short life. Such quartz and flint are unsuitable for the manufacture of silica products.

The tests necessary for the study of raw materials and of silica products are not numerous; several of them can be done in the works; the others can be done in the testing laboratory of the Conservatoire National des Arts et Métiers.

The complete analysis of the raw materials should first be proceeded with. The porosity test can be made by taking a known weight of rock or of the dry product; the samples are allowed to stay 24 hours in water and are weighed; the increase of weight represents the weight of water absorbed in the pores; by dividing this weight by the weight of the dry sample the porosity is obtained; this is not an absolute measurement, but it gives useful indication. Expansion is measured by means of a slide-gauge after heating the samples to various temperatures. The curve for crushing strength is obtained by Captain Bodin's method.

Tests at high temperature can be made in the industrial laboratory furnace which we have established with the co-operation of Captain Bodin under the auspices of Colonel Cellerier, Director of the Testing Laboratory of the Conservatoire National des Arts et Métiers. That furnace, provided with a Bigot recuperator (patented), permits several bricks to be heated at the same time to 1,750° C. in six hours, without using air-blast. Manufacturers can instal these testing furnaces in their works' laboratories.

Testing of Raw Materials.

Tests will only be undertaken on raw materials proceeding from quarries important enough to ensure the supply to the works for several years. It is useless to make tests on transparent quartz or chalk flint, which are unsuited for the manufacture.

The first test consists in heating the siliceous rock to 1,710° C.; first of all, the porosity of the sample has been determined as already described; if the rock melts at 1,710° C., or if it falls into powder, it is not suitable for the manufacture. When it remains compact, its expansion, porosity, and loss on heating are measured; it may be suitable for the manufacture. If it does not fall into powder during a prolonged heating to about 1,650° C. analysis also should be brought in to determine the quantity of foreign matter contained in the rock.

Experience shows that the expansions of siliceous rocks are very variable: quartzites suitable for the manufacture of silica products have expansions varying from 9 to 15 per cent.; products manufactured with rocks whose expansion is about 10 per cent. are much superior to those which are made with rocks whose expansion is about 15 per cent.

We will give as examples the composition and expansion of four different rocks.

1. Rock remaining compact and having at 1,700° C. an expansion of 9·8 per cent; this rock furnishes excellent products.

2. Quartzite rock, which remains compact when it is carried to 1,700° C., but which falls into powder when it is held for several hours at this temperature. Its maximum expansion is 11·70 per cent.

3. Poitou chalcedony, which remains compact when heated to 1,700° C., but which, at the end of several days' heating, falls to powder. Its maximum expansion is 6·60 per cent.

4. Argillaceous rock of Berneçay, which remains compact at 1,700° C. even after prolonged heating. Its maximum expansion is 4·70 per cent.

	I.	II.	III.	IV.
Silica	95·20	98·60	98·00	92·28
Alumina	2·30	0·70	0·60	5·10
Iron oxide	1·05	0·40	0·75	0·86
Lime and magnesia	0·45	traces	0·19	traces
Water and volatile matters ...	0·80	0·20	0·20	1·70
Not determined, and loss	0·20	0·10	0·26	0·06

No. I includes 2·30 per cent. of alumina, which constitutes the agglomerating material of the rock and the necessary flux in presence of silica and lime. No. IV, which includes 5·10 per cent. of alumina, melts at 1,650° C. in presence of 2 per cent. of lime because of its excess of alumina. Nos. II and III, which have respectively 0·70 and 0·60 per cent. of alumina, do not contain enough fluxes and fall into powder at high temperature at the end of a longer or shorter period.

These four examples indicate distinctly the role of alumina and the limits within which it should be present in order that a siliceous rock may be suitable for the manufacture of silica products.

Siliceous rocks from the same deposit often present variable composition and different hardness. As examples we will name certain quartzite deposits of Souvigny which comprise neighbouring or superposed beds: 1. Quartzite of excellent quality. 2. Quartzite (see No. II above) which much resembles the preceding, even under microscopic examination, and which is unsuitable for the manufacture because it falls into powder after heating to 1,650—1,700° C. for several hours. 3. Banded flint, which falls into powder at 1,400° C.

The manufacturer, then, will have to attend constantly to the quality of the siliceous rock which he employs, to inspect its composition, and to repeat the prolonged heating tests between 1,650° and 1,700° C. in order to be assured that the material remains very compact.

Ferruginous rocks containing from three to eight per cent. of oxide of iron are suitable for the manufacture of silica products; their utilisation has not yet been considered in France.

Manufacture of Silica Products.

With a good raw material the manufacture is very simple. The rock is ground so as to obtain angular grains of variable size, mixed with fine powder in suitable proportions. About 2 per cent. of fat lime is added, tempered in a suitable quantity of water, and the paste is worked up for 15 to 20 minutes. With this paste, pieces are made in moulds, either by hand or with lever presses or hydraulic presses. The moulded pieces

are dried fairly rapidly, and burned at as high a temperature as possible. During the burning the grains of the rock increase in volume, the siliceous powder, with the clay set at liberty by the grinding, and the lime, form together a glass paste which is agglomerated without melting completely but which softens at high temperature. This glass paste should not be too fusible, otherwise the products are softened too much at high temperature; it is sensitive to variations of temperature and it renders silica bricks brittle if heated or cooled too abruptly.

The employment of fine silica then is indispensable in this manufacture. It is necessary to use fairly large grains because they resist longer the corroding action of the furnace dusts and slags; but the size to be adopted for these grains will depend on the increase of their volume at high temperature; with a rock which expands 10 per cent., larger grains can be employed than with a rock which expands 15 per cent.

The manufacturer will be obliged to investigate for himself the mixtures and proportions which are most suitable. The ground rocks are passed through known sieves, the largest grains through No. 3 or No. 4 sieve; the mixtures being made into bricks, they are dried and taken slowly to 1,500° C. in five or six hours; they are held for four hours at this temperature, and they are afterwards submitted to the tests described above. When the most suitable mechanical composition and mixture have been found the manufacture is organized is such a manner as always to preserve the same proportions of large, medium and fine.

It has been shown that the large and medium elements should be angular; bricks made with these elements are more resistant to shock and to crushing than bricks made with rounded elements.

To obtain suitable grains and powder, the rocks are first passed through a jaw-crusher, regulated so as to produce pieces small enough. The grinding of these small pieces is done in two pairs of cylinders about 20 cms. wide and 0·70 m. in diameter; these cylinders revolve in a vertical plane with the same speed in contrary directions, and their separation can be regulated at will. The crushed rocks are brought into the first pair of cylinders, which grind them, giving to the largest grains the desired dimensions; these large grains are accompanied by medium grains and by a little fine. To obtain the necessary quantity of fine a certain proportion of crushed material is caused to pass into the second pair of cylinders with slight separation. Sorting machines, suitably fitted up, separate fine, medium, and large; they may be conducted into appropriate

silos, whence they are withdrawn for the needs of the manufacture

This grinding process is that which is adopted in works for grinding emery and abrasives; it is simple, it gives angular grains, whatever the degree of hardness of the material may be, it produces the necessary proportion of fine and the sorting machines always furnish the same classification, it is more economical than the use of five ton mills installed in certain works, and it abolishes the use of the tube finisher destined to produce silica flour.

The addition of lime and water is made by tempering in an appropriate quantity of water the desired proportion of slaked quicklime, and by pouring the mixture on the siliceous material. The intimate mixture of silica, lime and water is worked up mechanically, care being taken not to crush the silica grains; for this purpose kneading troughs in which the mixture is stirred for about 20 minutes can be used.

On leaving the pug-mill the paste is delivered for the manufacture of silica products.

The moulding of the pieces is done by three processes: I. By hand, in metal moulds. 2. In lever presses. 3. By the hydraulic press. The workmen who handle the paste should have their hands protected by rubber gloves against the corrosive action of the lime.

The process with the hydraulic press is in little demand. The hydraulic press is expensive, and it is necessary, in order to prevent wearing of the moulds, to provide them internally with movable plates of cementation steel. But bricks made by the hydraulic brick press are less porous than others, because of the powerful compression, and accordingly less liable to be attacked by the dusts and slags of the Siemens-Martin furnace.

According to observations which we have made on bricks thus manufactured with two varieties of rocks of different origin, and according to the testimony of metallurgists, bricks so pressed, made with these rocks, are superior, as regards life in furnaces, to those which have not undergone the same compression; but the porosity of bricks made with the first of these rocks is 7 and that of the other 7·50 per cent. The drying of silica products is done easily and rapidly in 24 hours in a well organized dryer.

Burning has a double object: 1. To increase the volume of the products as much as possible. 2. To form by combination of the fine elements a solid and resistant glass paste covering the grains of silica.

We have already seen that siliceous rocks suitable for the manufacture have not all the same expansion. There is still

another peculiarity which has its importance; the maximum expansion is realised when a rock is taken to 1,710° C. If it be heated to 1,500° C., for example, there is a partial expansion; keeping at this temperature for several hours, expansion is continued gradually, the rate varying with the nature of the rock.

The products of porosity 7 per cent., made with the first rock which we have just described, after heating to 1,500° C. for four hours, took nearly all their expansion; in fact if they are taken to 1,710° C. they only expand 0·30 per cent. The products of porosity 7·50 per cent., made with the second rock heated in the same conditions to 1,500° C., takes only a partial expansion; when it is afterwards taken to 1,710° C. it takes a new expansion of 2·50 per cent. Although these latter products may be of good quality, the first are superior to them; they can even be considered as being among the best silica products which are actually made because of their low porosity and slight expansion.

The temperature and the duration of the burning depend then on the raw materials. In most intermittent kilns which are employed for the burning the maximum temperature does not much exceed 1,400° C.; it is necessary then to prolong the duration of the burning, which involves an excessive expense for fuel. In the tunnel kilns that we have recommended, in which the temperature can reach 1,600° C., the duration of the burning is much reduced, and the economy in fuel is considerable

Conclusions.

In the résumé we have confined ourselves to questions which directly interest the manufacturer; we have left aside the scientific studies made on this subject, and we have passed by the questions which remain to be resolved. We have limited ourselves to showing to manufacturers why certain raw materials can be used and why others should be set aside. We have at the same time described the most rational and most economical processes of manufacture.

XVIII.—Notes on New Experiments on Silica Materials.

By A. Bigot, D.Sc.

1. The fused silica made from pure hyaline quartz falls to powder after firing for four hours at a temperature of 1,450° C.

2. The fused silica made with white sand is less pure than the fused hyaline quartz; it remains compact at 1,450° C., but begins to fall to powder at 1,650° C.

3. The fused silica made with silica bricks which contain about 3 per cent. alumina and iron oxide does not fall to powder even though maintained at 1,650° C. for many hours.

4. A silica rock which contains 5 per cent. of alumina melts at 1,730° C.; after the addition of 2 per cent. of lime the melting point of the mixture is about 1,650° C. and the silica product is not suitable for use in the Martin furnaces.

Conclusions.

(*a*) The raw silica materials, which are too pure, are not suitable for the manufacture of silica products, because they fall to powder after having been for variable periods in the Martin furnaces. Chalk flints and many types of quartz are among these too pure materials.

(*b*) The silica materials which contain from 2 per cent. to 5 per cent. of a mixture of clay, iron oxide and a small proportion of magnesia and lime do not fall to powder at high temperatures in the furnaces; they are suitable for the manufacture of silica products if their expansion at 1,710° C. is not too great. Some quartizitic and quartzose rocks and some dense flints are included in the class of good raw materials.

(*c*) The silica rocks which contain more than 3 per cent. alumina become too fusible after the addition of 2 per cent. lime and are not suitable for the manufacture of silica products.

Note.—The results of this work show that silica rocks and the products manufactured therefrom can be subjected to exact tests which avoid the necessity of lengthy and laborious researches on the part of the manufacturer, and which afford an excellent guide to the latter in his choice of raw materials and methods of manufacture.

XIX.—The Casting of Heavy Pottery.

By B. J. Allen.

ABOUT two years ago I read a paper before the Refractory Materials Section of the Ceramic Society and gave some idea of the methods employed to cast pottery under reduced pressure.

To-night I intend to briefly describe some further developments.

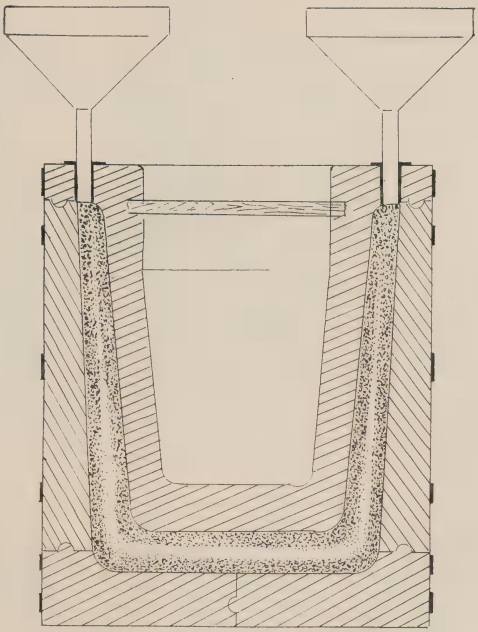


Fig. 1.

Only a few of the members present are directly interested in the articles I shall refer to, but I hope to put some ideas before you which I trust will be interesting.

I propose to deal first with the casting of heavy pottery in plaster moulds under ordinary atmospheric conditions, then

briefly to refer to the process described in my previous paper, and finally to describe the development and illustrate how the methods can be applied to the requirements of some of our local industries.

Fig. 1 shows an ordinary cored mould to produce open pots such as are used in glass works, the lining of steel ladles, or similar purposes. The slip is run into the mould through the funnels which are filled to give a good "head." If the mould and slip are in the right condition a fairly good casting may be obtained, but this method of casting has its limitations. It is very difficult to cast the centre solid, and it appears to be impossible to get anything approaching the same density of structure in the centre as

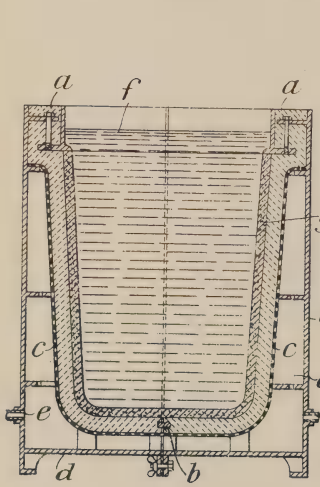


Fig 2.

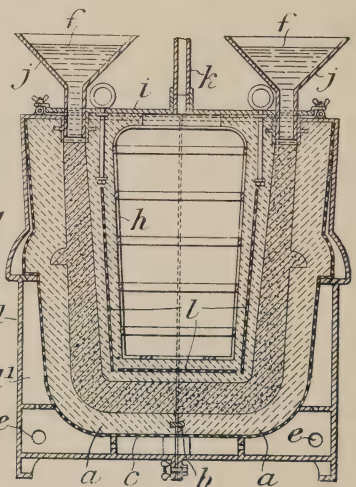


Fig. 3.

at the faces of the piece. Carelessness in filling the mould, or if the slip is not properly mixed, will result in a hollow casting. I have tried to show on the slide the sort of structure you are likely to get with this class of mould when casting articles 2 in. or more in thickness.

It is possible to get over the difficulty to some extent by first casting a core, placing it in the mould and casting round it. This will give a much better piece than casting without a liner or core, but the article will have obvious signs of lamination and be unsatisfactory for refractory purposes.

With this brief reference to some of the snags in manufacture by well-known methods, we will pass on to the casting of pots under reduced pressure.

Figs. 2 and 3 show two moulds fitted with airtight casings arranged so that the air can be removed from the space between the plaster and the casing by means of an air pump. In use, the slip is run into the mould through the funnels, or in the case of the open mould run direct into it, then the air is exhausted and the vacuum maintained until the result desired is obtained I do not think I need labour the point that as long as the clay is in contact with the plaster and the vacuum maintained the extraction of water from the slip will continue and the thickness of clay deposit increase.

If the thickness of clay is abnormal, or a quick casting required, pressure may be applied to the slip in addition to the vacuum.

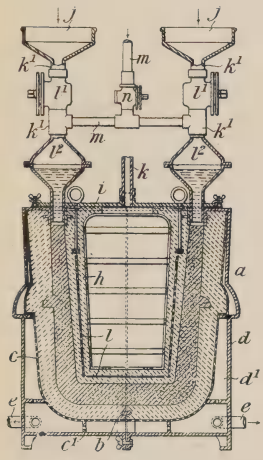


Fig 4.

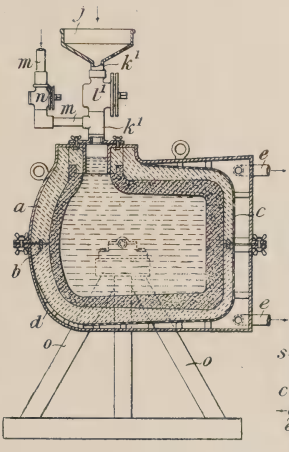


Fig. 5.

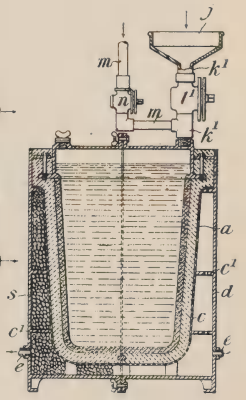


Fig. 6.

Figs. 4, 5 and 6 show the method of applying the pressure to three different moulds. Here the funnels are fitted with full bore stop-cocks and reservoirs through which the slip passes to the mould and below the stop-cocks a connection to an air compressor.

When the mould has been filled and working for a short time under vacuum the stop-cocks to the funnels are closed and compressed air admitted to the top of the slip. The advantages of applying compressed air to the one side moulds, shown by Figs. 5 and 6, is not so important as its application to the cored mould shown by Fig. 4.

I have already shown the possible defects of casting in a two-side mould; now if you require a very thick piece, with

tapering sides, the difficulty will be intensified. It will be obvious that if the bottom is twice the thickness of the top the rim will be cast dry and hard, whilst the interior of the bottom and part way up the side is still soft. The problem we have to deal with is, how to get the slip supplied to those thick parts before the thin parts are hard. The application of pressure to the slip supply will do this. You all know the action of a filter press and how soft the clay remains in the vicinity of the supply nozzle, and how the soft supply can be traced down the centre of the cake of clay. The same principle is applied to the casting of the pot. The pressure forces the clay slip through the thin part and keeps the way open until the lower part will take no more, then fills up to the inlet feed and makes a sound pot. The casting of a pot under these conditions gives you a beautiful surface of fine clay on both inside and outside of the piece.

This type of mould is very suitable for lining the inside of a refractory pot with special material. For example, zirconia may be cast on the core by dipping, and then placed in the outer mould and the fireclay or other refractory mixture cast on it.

We now come to the casting of a covered pot and it is here, I think, that the vacuum process is indispensible if a perfect piece is to be produced.

Fig. 7 shows a modification of the mould illustrated in my previous paper. It is constructed in four parts: base, two side moulds and mouthpiece. You will notice that the vacuum chamber at the sides only extends a short distance. The object of this is to permit of the base and sides near the bottom being cast thicker than the top. No provision is made on this mould for tilting to empty out the superfluous slip. The labour in tilting can be dispensed with by using a vacuum tank and sucking the superfluous slip from the mould. The saving of labour is a big consideration now, and the removal of the slip by suction is a cheaper, simpler and much cleaner method of removing what is not wanted.

So far I have only dealt with moulds where a jacket is applied to each individual mould which on account of cost could only have a limited application.

Fig. 8 illustrates a development in the construction of vacuum casings and shows how the process can be simplified, cheapened, and made adaptable to various sizes of articles The drawing shows a "Dandy" pot such as is used in some glass works. The mould is constructed with a framework of wood arranged with runners so that the mould can slide into the vacuum box like a drawer into a chest. The vacuum box shown is of wood

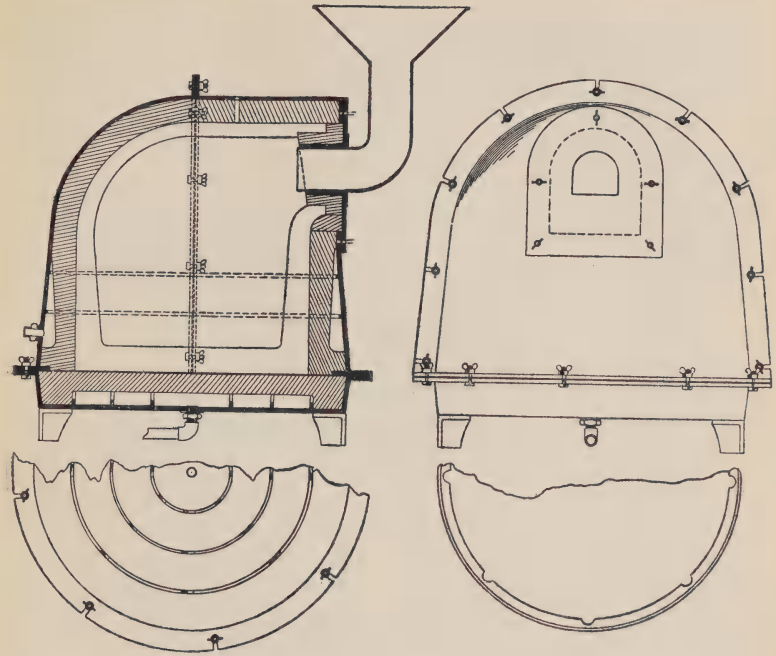


Fig. 7.

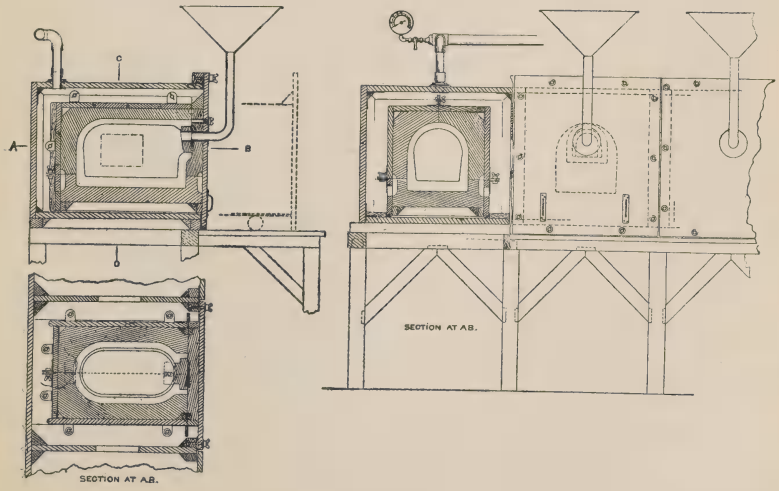


Fig. 8.

covered on the outside with zinc, and the joint at the front made with a soft rubber washer tacked to the case. This arrangement permits a number of moulds being put into one vacuum chamber. The wood runners can be constructed to adjust the size of mould to the box, serve to protect the plaster from injury, and also form an easy attachment for the wire netting with which the mould is re-inforced.

This method is not confined to the manufacture of small articles. A 38 in. dog house pot, such as is illustrated by Fig. 7, can be dealt with in a similar way, but in this case wheels would be fitted to the bottom of the mould to permit easy withdrawal, etc. I may mention that over 30 cwts. of slip is required to fill a 38 in pot mould.

Now coming nearer home. Fig. 9 shows a mould for casting enamelled fireclay lavatories under vacuum. The construction of the plaster parts only varies from the moulds used for the ordinary process of casting in the adoption of the wood framing. and the back mould which is arranged to be attached to the airtight door. With this arrangement the white engobe can be filled into the mould and cast up to any desired thickness, then the superfluous material run off and the fireclay run in and cast up solid.

The demand for fireclay with a thicker engobe will be insistant in the near future, and this method of production or an equivalent must be used. The life of the engobe, often less than $\frac{1}{16}$ in. thick, such as at present sold, is not enough, and it is up to the enamelled fireclay manufacturers to produce something better.

Fig. 10 shows a bath mould constructed on similar lines. In this case a ferro-concrete chamber with metal front and door are shown, and the mould supported on "T" iron bearers which act as runners. The plaster mould is framed in wood having suitable apertures to expose the plaster and does not vary much from a mould for pressing baths as far as the outside mould is concerned. The engobing and filling with fireclay take place in much the same way as described for the lavatory. When cast up the mould is withdrawn and the core removed, then the front and side moulds, leaving the bath resting on the base mould ready for upending and removal to the stove or glazing shop. The provision of duplicate bottom parts would permit the complete mould being immediately returned to the vacuum chamber and another bath cast. I am expecting that in the near future porcelain enamelled baths of the finest quality will be produced by this method at the rate of one finished bath per mould every twenty-four hours, and at a cost which will permit prices to compete with the better class of enamelled iron.

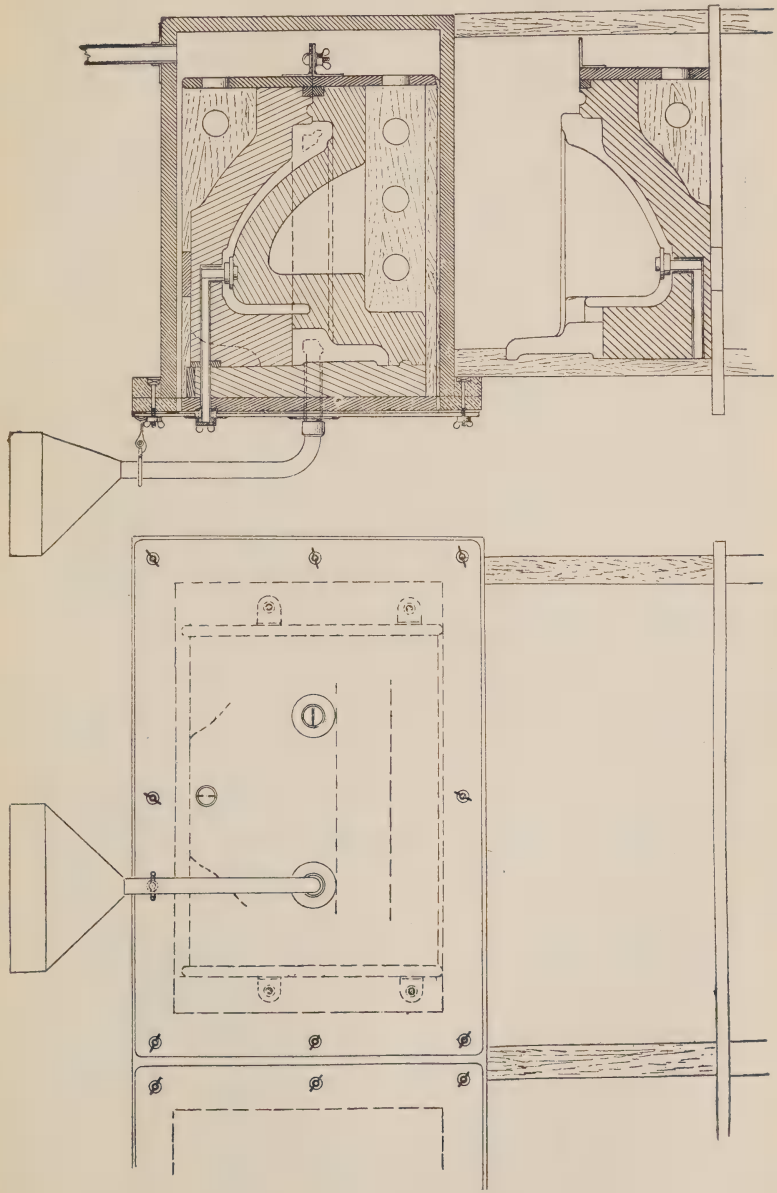


Fig. 9.

The space at the top of the ferro-concrete chamber is not wasted. Lavatory moulds such as are shown by Fig. 9 could be accommodated and leave sufficient room for the workers on the top of the platform without interfering with the bath makers. The chamber for bath moulds could also be used for gas retorts or any other big piece of similar overall dimensions.

At a later date I may show you the drawings of a factory designed to employ this method, and illustrate how the process lends itself to efficient organization and maximum production with a minimum of labour.

Fig. 11 shows the arrangement of multiple moulds for casting Sinclair insulators. In this case a two-piece plaster mould is used and the cores, with screw thread complete, are of porous pottery, also cast. The slip is fed to the bottom row of moulds, runs up the duct at the back, fills the top row and then gets a head of slip by running up the pipe to the level of funnel. If any air should be imprisoned the small ducts at the base of the cores which are connected to the vacuum space eliminate the danger as soon as the vacuum is produced. The cores need not be porous if a high vacuum is used. Specially designed metal cores with a plaster filling may be used.

For high tension electrical insulators I think there is a great future for vacuum casting. If reconstruction goes on the lines already suggested, and high voltages are carried long distances, then the demand for this class of pottery will be enormous, and I am convinced that throwing and turning will not fill the bill. High voltage electricity will find the weakness in a thrown piece in a way nothing else will, and there are often weaknesses in thrown pieces of large sizes as every maker of electrical porcelain knows.

The same casing which is designed for Sinclair insulators is also suitable for large high tension intake insulators. Where many of the latter are made it would be advisable to design the plant for the large articles and adopt the smaller multiple moulds to suit.

In the near future I hope to be able to show you examples of the different structures which can be obtained by varying the degree of vacuum and pressure. My contention is that you can get more clay in a given space by vacuum than by any other commercial process and the piece, when it leaves the mould, is very much dryer than can be obtained by either pressing or ordinary casting.

In conclusion I should like to show illustrations of two vacuum pumps, Figs. 12 and 13, either of which will produce a vacuum within 6·5 in. of atmospheric pressure.

An efficient pump is indispensable for satisfactory working, and the apparatus illustrated appeals to me as being ideal for

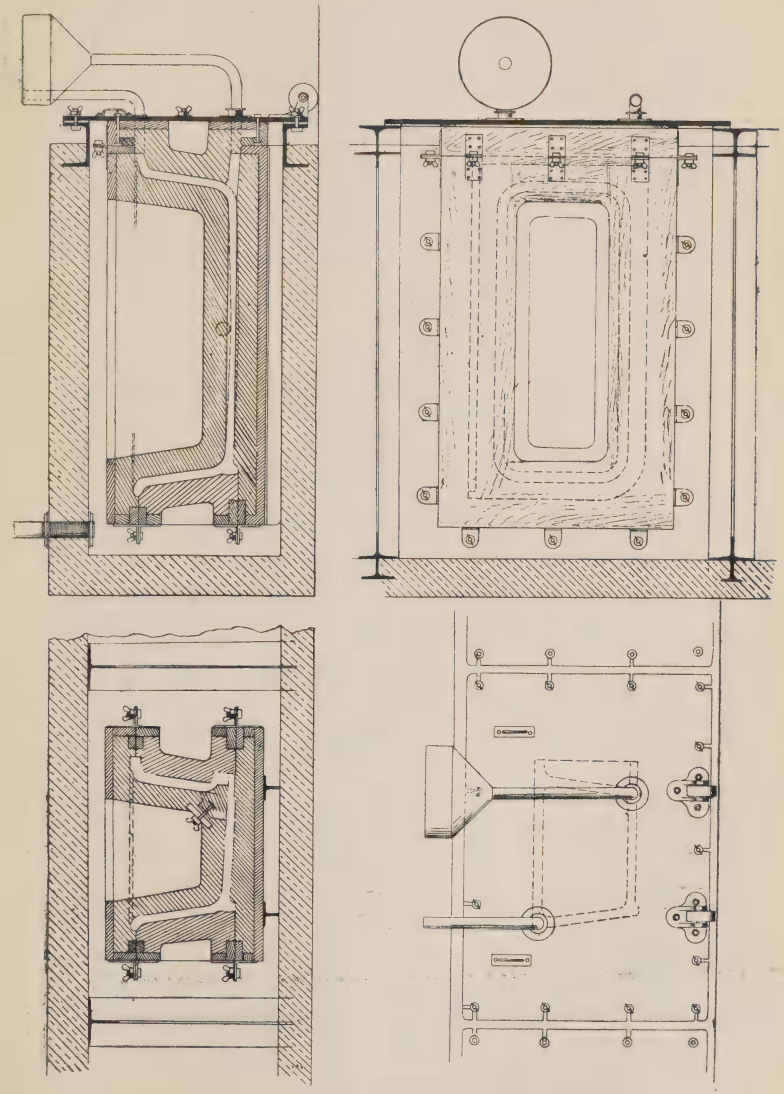


Fig. 10.

the purpose. At one large factory where a multijector air pump is employed, a vacuum of 29·5 in. was shown on the gauge

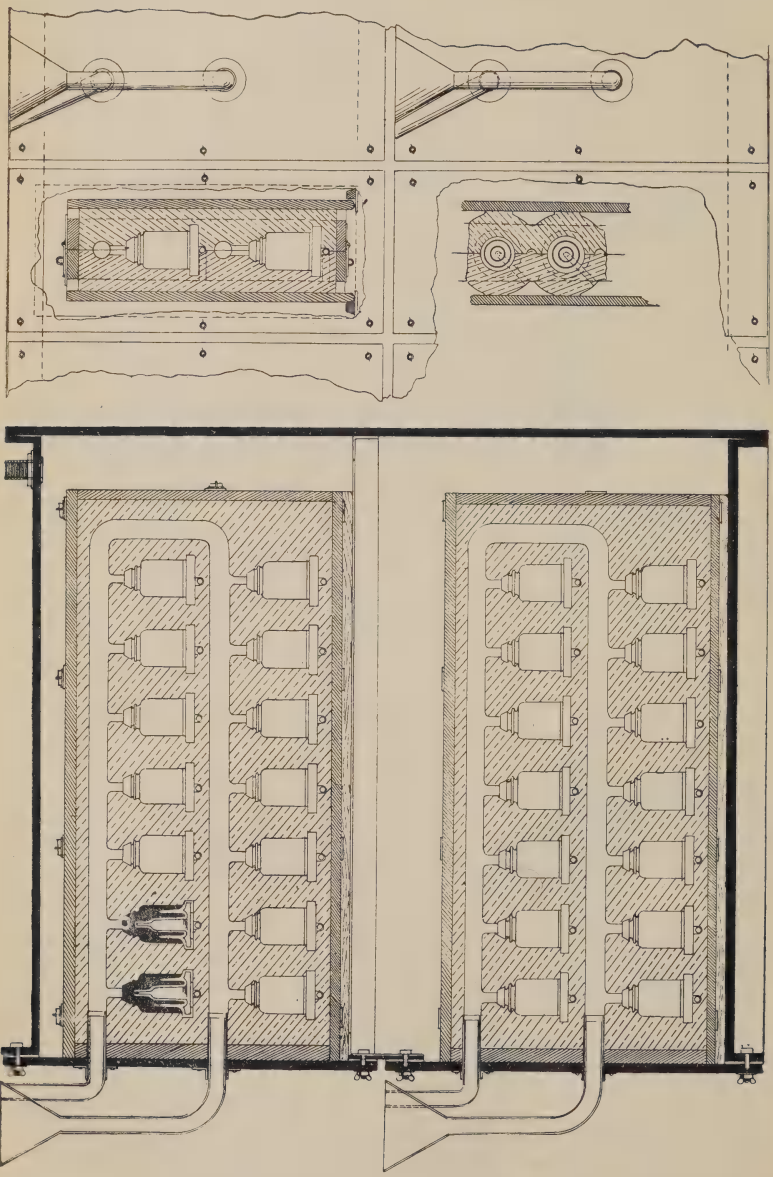


Fig. 11.

with the barometer at 30 in. The working conditions, however, were very favourable. Superheated steam at 120 lbs. pressure

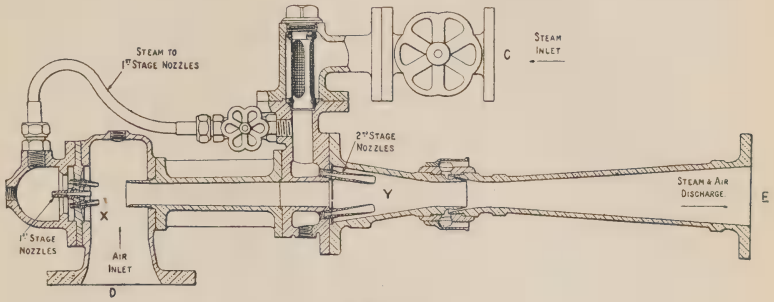


Fig. 12.

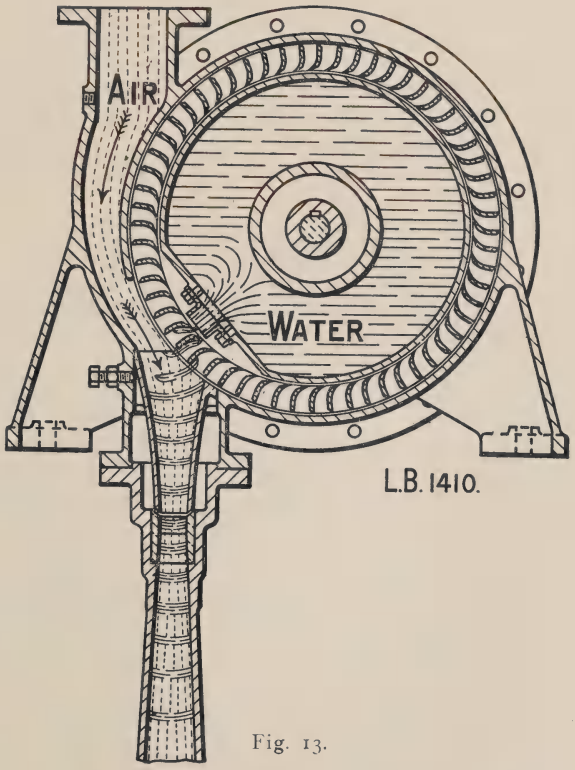


Fig. 13.

was used, and the casting of a white plastic body was $1\frac{1}{2}$ in. thick on the mould.

DISCUSSION.

Mr. A. LEESE:—I would like to ask Mr. Allen several questions. In the first place, what is the particular advantage of vacuum casting? Secondly, what is the advantage of using a core in the mould? Thirdly, whether he has tried feeding the pots at the bottom instead of at the top? And fourthly, how far he has tried this method in a practical way? A core must be a big trouble in casting pottery, and it is not always the best way, because, so far as I know, you do not get the body so even in composition and construction as you would with an open filling mould. Then Mr. Allen has made reference to thrown and turned insulators. I was wondering whether the lecturer has tried these insulators in an exposed atmosphere for any length of time, in both the winter and the summer, because there is a wide difference between cast ware and thrown and turned. I can hardly see how a vacuum is equal to pressing by hand if that is done in a proper, workmanlike way. I must say that the paper is a very elaborate one, and very well illustrated. I should be pleased if the lecturer could answer these few questions. Even if they are not properly put someone may learn something by the replies, and after all that is what this Society is for.

Mr. W. CLEVERLY:—I would like to ask whether the running in of the fireclay after pieces have been engobed with zirconium does not tend to remove the zirconium coating, and also if the vacuum is sufficient to remove any air bubbles which might be carried into such a thick piece as a glass-pot by the slip being under pressure.

Dr. MELLOR:—I would like to congratulate Mr. Allen upon what I consider a brilliant exposition of the whole principle of casting by pressure and vacuum. As is known quite well, vacuum casting (so-called) was practised in a crude sort of way at Sèvres many years ago, but I think Mr. Allen's developments a most decided advance. As Mr. Allen knows, there was trouble in the early days of the war in getting suitable glass-pots for the making of optical glass for periscopes and various appliances for the use of our soldiers before the glass was taken up at Sheffield, and I remember speaking to Mr. Allen and asking him if he could not hasten up the process somehow by casting glass-pots. I remember pressing it fairly strongly to him at the time. I was referring then to the ordinary casting of glass-pots under usual conditions. I had one doubt about the casting. A glass-pot has, of course to withstand the action of a corrosive, molten glass for a good long time.

The conditions are very much the same as those which occur in the bottom of a frit kiln making a lead frit. The corrosive action is very great, and under ordinary conditions of casting I am not sure that the cast pot would not be just a little on the porous side. I spoke to Mr. Allen about this last week. I think that with his application of vacuum pressure to the casting he will be able to get a better "density," and a better all-round result than with ordinary casting. In large articles which are to be subjected to great heat, one of the difficulties is to get the pot of homogeneous texture throughout. When the pot is built up by hand this is exceedingly difficult, and a great many of the faults in refractories are, in my opinion, due to the heterogeneous texture, so to speak, of the body. I think with Mr. Allen's process, if he can so arrange it that it is almost fool-proof, and bring it under perfectly easy control, which I have no doubt he will be able to, it will be possible to produce glass-pots which will give a much better result than some of those now in use. Mr. Allen's reference to electrical goods is also interesting. The breakdowns are due not so much to the materials as to interruptions in the continuity of the material, by flaws, blebs, and the like. These are the places which first break down under high voltages.

Mr. B. J. ALLEN:—Mr. Leese's questions are always interesting, and I will do my best to reply to them. But I would like to explain at the start that the paper is a scrappy one, only supposed to occupy twenty minutes, so that it has not been possible to fill in all the details that may be desired. It was only intended to be a brief outline of the development from simple casting to vacuum and multiple casting, and to show modifications of the methods.

With regard to the advantages of vacuum casting, I think Mr. Leese has supplied his own answer. In the first place, I only suggest this process for heavy articles of great thickness, or where you require a definite density.

The difference between an ordinary cast article and a thrown and turned one is admitted. We all know that the cast insulator, cast under ordinary pressure, is not as good as the thrown and turned one. It is to get the cast insulator superior to the thrown and turned one that I suggest the vacuum process. The advantages for certain refractories is that you can get a density under vacuum and pressure that is a physical impossibility by ordinary pressing or by casting without a vacuum. A piece cast under vacuum with the maximum pressure will give more clay in a given space than it is possible to get by pressing. All the time that you are casting the piece under

vacuum you are carrying fine clay into the fissures or pores and feeding them full. The great advantage, however, is in the homogeneous structure produced. If you break down a piece of clay with hot water the structure can easily be determined. Pugged clay breaks down in parallel lines, a thrown and turned piece in spiral lines, a pressed piece breaks down so as to show all jointing of the clay, whilst a vacuum cast piece does not appear to show disintegration along any lines whatever.

With regard to using a core. To cast a piece more than three or four inches thick you would have a difficulty in getting the required thickness on a single face of plaster within a reasonable space of time, and often the interior of the article is required with a fine face, whereas the outside does not matter so much. Under these conditions it is necessary to have a core, and where you employ a core you require to get some means of filling the centre of the casting, such as I have illustrated in my first diagram. Otherwise you get a defective piece.

Concerning the weathering of insulators, etc. The difficulties of atmospheric conditions we know. But my contention is that you can cast insulators under vacuum so that faults such as are common in ordinary cast articles or thrown and turned will be eliminated.

With regard to feeding the moulds at the bottom instead of at the top, this does not make much difference, because with a vacuum the pressure will be the same all over the piece. The clay casts up on the top of a covered pot just the same as it does at the bottom providing the plaster is sufficiently exposed. The diagrams, however, show the feed at the bottom wherever the design of the article permits.

In reply to Mr. Cleverly, the zirconium or other engobe on the plaster core is held in position by the vacuum that is maintained inside the core, and it is possible to run the supporting material round it without any great disturbance. There will be a certain amount of friction caused by the clay or other refractory running round, which will carry some of the engobe along with it, but the bulk of the material removed will be carried along automatically with the slip, and cause no trouble. Supposing it does mix with the fireclay in the immediate vicinity of the engobe, that is likely to be an advantage rather than the reverse, and if you cast it on sufficiently thick and get it sufficiently dry there will be no difficulty. The same remarks are applicable to the casting of an engobe on to a lavatory mould to be filled with fireclay. In this case there is really a big advantage in the little friction which causes an

intimate mixture between the fireclay slip and the engobe just where the junction takes place.

The application of pressure to slip does not put air into the material at all, the tendency is to take it out. Pugged clay, which has not been slipped, contains from 5 per cent. to 15 per cent. by volume of air. Slip should not contain more than 2 per cent. or 3 per cent., and the bulk of this would be removed under vacuum, so that the advantage of vacuum casting insulators, glass-pots, etc., will be obvious.

XX.—Note on Apatite Substituted for Bone Ash.

By N. B. Davis.

ALTHOUGH some work appears to have been done with the idea of using apatite in place of bone ash in English bone china bodies, the results have not been decisive, and the problem remains an open one.

The owners of Canadian mica-apatite mines are interested in the problem as it is important that some use be found for the apatite, aside from the fertiliser industry. At one time this mineral was mined on a large scale and shipped to England to be manufactured into acid phosphate, but the discovery of the cheap phosphate of the south closed the mines of the north.

The apatite occurs in irregular masses and veins, and from a number of mines can be cobbed clean of the associated minerals. A typical analysis of such material from one of the largest pits is as follows:—

SiO_2	0·06
Fe_2O_3	0·72
Al_2O_3	0·72
CaO	55·60
MgO	0·33
Na_2O	0·25
K_2O	0·25
H_2O	0·20
Cl	0·50
F	3·10
P_2O_5	39·24

Several papers dealing with substitutes for bone ash have appeared in the TRANSACTIONS, the most important being that by Edwards, published in 1904. It has been claimed that bone ash owes much of its value to the porous condition of the individual particles, but Edwards negatives this by getting as good results with artificial phosphate.

Preliminary tests were made with typical bone china bodies substituting apatite for bone in the following proportions:—

	1	2	3	4
Apatite	42	39	35	32
Felspar	15	16	17	19
China clay ...	33	34	34	35
Flint	10	11	14	14

The material was ground for from ten to forty-eight hours in a ball mill, and worked by casting and plastic methods into a series of test cups. It showed excellent casting properties and plasticity, both being improved by the lengthening of the grinding period.

The bodies were burnt to cones 8, 9, and 12, and greatest translucency was developed in No. 4 at cone 9. All pieces at cone 12 showed deformation and bloating.

In colour the ware had a slight greenish tinge, giving it a certain distinction.

Similar results were obtained in tests carried on by another worker with bodies in which no flint was used.

Samples of the Canadian mineral were sent to a number of English potteries for testing, but to date no returns have been received. Perhaps members of the Society can report on the matter.

Bone ash costs the English potter, enameller and glass-maker something like £10 to £12 per ton, and it should be worth while considering apatite at £6 to £7 per ton. Clean cobbed mineral could be delivered for this lower price in amounts of 500 to 1,000 tons yearly.

DISCUSSION.

Mr. BERNARD MOORE:—I may say that I tried apatite a good many times some years ago, but my experience was that the resulting ware would not stand in the oven; it would not keep its shape. I have not the least doubt that a certain amount of apatite might be used in place of bone ash, but it makes an inferior body. At least I have never succeeded in making anything that was at all good with it. I have tried many similar things from time to time. I once made a fairly successful body—a body that could be used quite well—from phosphatic guano, but it would not compare with a bone china body; the phosphatic guano was not such a good source of phosphate. A very good colour indeed can be obtained with precipitated phosphate, but the ware does not stand so well in the oven.

Dr. J. W. MELLOR:—I have many times heard Mr. Moore speak of trials that he has made with the mineral phosphates long before we began to hear of Canadian apatite, and, from what I have heard Mr. Moore say at various times, the point of the whole thing seems to be that you can make a perfectly good china providing you are only going to test it in the form of

small slabs, but directly you begin to make ware in bulk, on a manufacturing scale, the percentage loss, through deformation, squatting, under-firing and over-firing, etc., goes up very high. In fine, the margin of safety with the purer forms of mineral phosphates is smaller than with bone ash. Some of this work has been repeated by students, and they confirm the view previously expressed by Mr. Moore.

Mr. A. HEATH:—Mr. Davis asks for a reason why he has not had a report upon his samples. Some considerable time ago I received a letter from Canada saying that I was being sent a sample of apatite. Ten weeks afterwards it had not arrived, and although I have written four times I have never yet received the sample. Possibly others to whom the samples were sent may have had the same experience, and this may account for Mr. Davis' firm not having had any report.

With regard to the possibilities of apatite as a substitute for bone, I have not had an opportunity as yet of doing any experimental work with this particular material. I have, however, been doing some experiments on another line. I obtained a very nice, translucent body in the experiments, and thought it would be possible to make china with it on a commercial scale, but we found, when we went further into the matter, that the limits between under-fired and squatting were so very narrow that the material was useless for practical working. At cone 5 the ware was not properly fired up, and at cone 6 it had squatted.

I have before me a contributed article to *The Pottery Gazette*, published in 1896, in which reference is made to a substance called "ceophelsite." In this particular article china manufacturers are exhorted to take heart, as a perfect substitute for bone china had been found. I went to some trouble to try to get into touch with the writer of that article, but learned that he was dead. That trail for a substitute for bone had, therefore, to be abandoned.

Mr. N. B. DAVIS:—A discussion of this paper has failed to bring out any definite information as to the source of the material used, how it was prepared, the proportions to other ingredients, and the character of the results. It was my hope that guiding data might be made available for future work. If it is possible to make small test-pieces of ware, there surely is a way to make larger pieces by adjusting the conditions, and if the science of ceramics is to advance the data of failure must be recorded as well as that of successes. From my work with bone and apatite I believe that the principal trouble of deformation is caused by the character of kiln used. The usual

type of potters' kiln keeps the ware in heat too long near its maturing temperature. The remedy would appear to be more rapid firing in tunnel kilns.

Another matter that requires attention is the free silica content. My more recent experiments indicate that better results are to be obtained by not using flint in the body. I am sorry that Mr. Heath failed to receive a sample of apatite. In all probability a submarine got the steamer. Now that the peace treaty has been signed, and the seas are free, I will be glad to forward samples of Canadian apatite to anyone interested.

XXI.—Mica Schist for Lining Cupolas, and Steel-Converters.

By P. G. H. Boswell.

THE consideration of the refractory materials used for lining such furnaces as cupolas and steel-converters may be regarded as appropriate at a meeting held in the Middlesbrough district. The following notes, however, deal with a material widely (but not exclusively) used in America, and are offered in the hope that a search may be made among similar British materials with the view of prolonging the life of our furnace linings.

In British practice the material in common use is the so-called "ganister," which consists of a sloppy mixture of broken quartzite or ganister rock (*sensu stricto*) and fireclay or ground ganister. Such a mixture is used to a small extent in American foundries, but a large number of works employ a rock belonging to the mica-schist group, which is quarried in Pennsylvania and New Jersey, in each case not far distant from Philadelphia.

The quartz mica-schist is of Cambrian age and is quarried at localities about two miles north of Jenkintown or about ten miles north of Philadelphia. The geology of the district is described in the Philadelphia folio of the United States Geological Survey.

The Glenside and Edge Hill rocks are very similar to one another, but the following description actually applies to the latter material, which is known commercially as "The Edge Hill Silica Rock Company's Mica-Schist."

In hand-specimens the rock is cream coloured and of clean appearance. Clayey and dusty minerals or decomposition products are absent. The rock, although foliated like all schists, is fine-grained and compact. Sections across the edges of the folia and cleavage planes are firm and compact, and joints break the rock cleanly and firmly across these planes The surfaces of the folia are lustrous and silky with small plates of white mica (muscovite). Thin bluish bands interpenetrate the white folia and constitute about one quarter of the bulk. The rock is fairly hard, and even the foliation surfaces cannot be scratched by a knife without some difficulty. Nevertheless, the rock is easily split parallel to the folia and worked into

the required shapes. Under the microscope, a section cut perpendicular to the foliation planes has the appearance shown in the photomicrograph, Fig. 1. The bulk of the rock is composed of the mineral quartz, the grains being of variable size but not drawn out into lenticles. Many of the grains show variable extinction, "strain-shadows" passing over them as the slide is rotated between crossed nicols. This phenomenon is usually accepted as evidence of pressure during metamorphism, which has left the crystals in a condition of strain. The quartz appears to be free from inclusions other than wisps of muscovite mica.

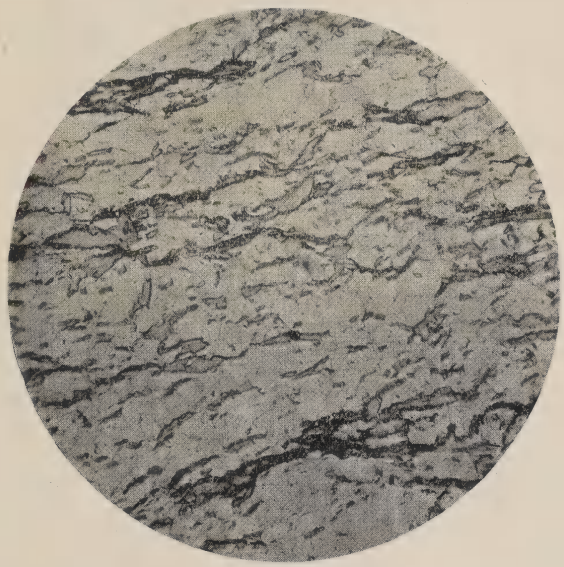


Fig. 1—Photomicrograph of quartz-mica-schist perpendicular to foliation planes. Edge Hill Silica Rock Company's Mica-Schist, New Brunswick. N.J. Viewed by transmitted light. Magnification: 25 diameters.

The latter seem to indicate a certain amount of recrystallization of the quartz surrounding them. Wisps and elongated crystals of muscovite mica are fairly plentiful in the rock, many being stained pale brown with limonitic matter (hydrated ferric oxide). A small quantity of ilmenite is also to be seen. The rock is thus rather a quartz-schist than a mica-schist, and has probably originated by the metamorphism of a partially decomposed felspathic sandstone. The foliation is produced by the flaky crystals of mica, and the arrangement of the quartz-grains

in layers under pressure. A chemical analysis of an average sample of the rock, kindly carried out by Dr. H. F. Harwood, of the Imperial College of Science and Technology, London, S.W., is as follows:—

	Per cent.
SiO_2	81·58
Al_2O_3	10·04
Fe_2O_3	2·24
FeO	0·32
MgO	0·19
CaO	0·22
Na_2O	0·08
K_2O	3·38
H_2O+	1·74
H_2O-	0·27
TiO_2	0·34
CO_2	none
P_2O_5	trace
MnO	trace
BaO	0·03
Cl	trace
Total	100·43

Owing to the considerable amount of muscovite mica present, in addition to some potash felspar, it is not possible to calculate the rational or mineral analysis from the above ultimate analysis. Suffice it to say that, assuming muscovite to have the composition $H_2KAl_3Si_3O_{12}(=2H_2O.K_2O.3Al_2O_3.6SiO_2)$, if the potash were all present in the form of muscovite, 11·02 per cent. of alumina would be required. On the other hand, if the potash were present as potash felspar alone, 3·67 per cent. of alumina would be necessitated. As the actual alumina percentage is 10·04, and no amount of clayey material could be observed, it is clear that the potash is largely present as muscovite mica; a small quantity has also gone to form potash felspar (presumably orthoclase, from the microscopic examination). From the point of view of the quartz-content, it is practically immaterial whether the potash is present as mica or felspar, for the proportion of silica required to combine with 3·38 per cent. of potash is in either case approximately 13 per cent. About 68·6 per cent. of silica is therefore present in the free state, that is, in the form of quartz. The percentage of water driven off above 105° C. ($=H_2O+$, 1·74 per cent.) is practically all accounted for as hydrogen in the muscovite, and combined water in the iron oxide.

Method of use.—The rock is built by masons into the walls of converters and cupolas, inside the firebrick casing, in the usual way. The Edge Hill Company rightly insists upon the rock being set with the cleavage edges, and not the faces,

Fig. 2.—View of the Edge Hill Silica Rock Company's Mica-Schist Quarry, New Brunswick, N.J.

forming the inner wall. The rock is obviously liable to chip and spall if the foliation planes are set parallel to the walls. Nevertheless, the writer saw several cases in the States where the rock had been so set, and the extraordinary thing was the successful way in which the material withstood the effects of hot metal. The schist is set in a mortar usually made from the local fireclays, but sometimes from the crushed rock itself. The company claims, and with good reason, that the rock is easily dressed, that it leads to the production of smooth walls, and that it does not easily cut back. To these qualities the writer can testify, but has no figures immediately at hand regarding the number of heats usually obtained from linings of this rock, nor any results which serve to show how far the quartz present has suffered inversion to cristobalite or tridymite. It is claimed that the rock glazes under severe heat, and that slag and clinker do not adhere to it. The glazing is explicable when we consider the quantity of potash present. Indeed the rock is, in practice, actually more refractory than its chemical composition would lead us to expect.

For the benefit of those who wish to make a trial of the rock in British foundries it is put up in barrels of 500 lbs. each ready for export at New York City or Philadelphia. The favourable results of its adoption in America are indicated by the rise in production in recent years. The figures issued by the United States Geological Survey show an output of nearly 40,000 (short) tons in 1917, which is an increase of over 6,700 (short) tons on the production in 1916.

It is to be hoped that this brief account of the use of mica-schist in the steel industry may lead to an investigation of home resources of the rock. Schists occur in vast quantities and in great variety in the Scottish Highlands as well as in a few scattered localities in England and Wales. Quartz-mica-schists of similar appearance to the American rock are not uncommon in Scotland. It remains to be seen whether they can be put into economic use.

The thanks of the writer are particularly due to the Edge Hill Silica Rock Company for additional samples, illustrations, and information, and to the numerous presidents, vice-presidents and superintendents of steel corporations who gave him so cordial and open a welcome in American steelworks.

DISCUSSION.

Dr. A. SCOTT:—In certain parts of the world the use of mica schist for furnace linings is no recent innovation. I think

that Wallerius mentions somewhere that it was used in Sweden as early as 1740, and there are some subsequent references to its use in that country in the eighteenth century. Although it seems to be widely used in America, I have always held the opinion that either it is used in such a way that it is not subjected to very great heat or that the so-called mica schist is not exactly the rock to which we should apply the name in this country. I have tried, in a laboratory furnace, a rock belonging to the Moine Gneiss series of the Scottish Highlands, more like the argillaceous Moine, but found it rather unsatisfactory. At temperatures above 1,200° C. it tended to split along the cleavage planes, particularly along those bands rich in mica. This tended to occur both when the cleavage was placed vertical and when placed horizontal. I should like to ask Prof. Boswell if such splitting along mica-rich layers tends to occur with the American rock.

Mr. ACTON:—I should like to ask Mr. Boswell—as we have various schists in the North Wales district—if he has made any petrological examinations of this material after it is used in the converters in America. And if so whether the failure of the material was roughly what I might call mechanical or failure of conversion. I rather understand him to say that from the way the blocks were got that the failure might be due to mechanical conditions rather than to the failure of conversion conditions under temperature. Can he give us any information from the examination of used materials?

He also referred to the "glaze" condition of the surface, has he any information as to what were the conversion conditions of that material?

Mr. HANCOCK:—The production of a glaze seems very fortunate, for a schistose material would be much more resistant to attack if this glazing takes place than if the reverse were the case.

There is one point strikes me, and that is that this material is dressed so easily; one would have thought there would be considerable difficulty in working it on account of the foliated structure. The fact is certainly remarkable that in several cases the lining behaved satisfactorily when set with the foliation planes parallel to the walls.

Mr. RIDGE:—While on a recent visit to one of the fireclay deposits in Yorkshire I found a micaceous shale which was highly refractory; on burning some test-pieces it lost its

unprepossessing appearance and became white. It was a shale from Denholm, near Sheffield, and should be worth thorough investigation.

Micaceous shale was formerly largely used on the Continent, but when the price of labour rose it went out of fashion in consequence of the high cost of cutting and dressing, but some ten years ago it again came into use. The raw shale was carefully cut to size and used for building furnaces without any preliminary burning.

Prof. BOSWELL:—In reply to Mr. Acton, the author regretted that no opportunity had yet arisen for the examination of the schist after its use in converters. He formed the opinion, however, from the megascopic appearance of the rock, that such trouble as arose was mechanical and due to the splitting along foliation planes, where mica occurred. The "glazed" condition seemed to be due to the fluxing of the mica and possibly of potash felspar, the quantity of alkalies (almost $3\frac{1}{2}$ per cent.) being noteworthy in this connection. He agreed with Mr. Hancock that the glazing was in some respects protective in a foliated rock.

Finally, in reply to Dr. Scott, the author desired to emphasize the fact that the rock, although commercially termed a "mica-schist," was not highly micaceous in hand specimens. It resembled more closely the quartz-schists of the Moine Series in Scotland, and it was to such rocks in Scotland, and possibly in Anglesey, that he looked for British parallels. The splitting which took place in the American rock was certainly along mica-rich layers, but was less frequent than a geologist would be led to expect.

XXII.—Note on a Silica Brick from the Roof of an Open-Hearth Furnace.[1]

By J. E. Stead, D.Sc., F.R.S., Vice-President.

THE following note embodies an investigation on a silica brick taken from the roof of an open-hearth furnace at the works of the Cargo Fleet Iron Co., Ltd., Middlesbrough. The object of this investigation was to confirm, or otherwise, the very careful work of E. Rengade, who communicated a paper on the subject to the Academie des Sciences of Paris on May 13th, 1918 (*Comp. rend.*, 1918, **166**, 779–781), a translation of which appeared in abstract in the *Iron Age*, August 1st, 1918, 270–272. He says:

A subsidiary object of the investigation was the chemical modification to which the bricks are subjected under the influence of the dust particles floating in the atmosphere of an open-hearth furnace. Four different zones can be distinguished in these bricks.

A. The lower layer immediately in contact with the flames is glazed and frequently shows protuberances depending downwardly (stalactites) and of variable lengths. The coloration of a freshly broken surface is a light grey, and the mass has a perfectly homogeneous aspect and frequently is dotted with blowholes.

B. Above this zone and generally very sharply separated therefrom, follows a black or dark-grey zone, likewise having a very homogeneous aspect and a very considerable crushing strength.

C. A transition zone which, most frequently, is indicated by the appearance of white specks in the middle portion of the black zone, which are the original thicker quartz grains not completely absorbed. The black zone then merges into a pale brown zone in which the heterogeneous structure of the original brick again becomes visible, and which appears as if only impregnated with a fused substance having a brown coloration.

D. The uppermost layer of the brick did not undergo any detectable alteration.

Composition of Zones in Per Cent.

Brick from Acid Open-Hearth Furnace.

	A.	B.	C.	D.
SiO_2	79·60	74·76	91·00	95·30
Al_2O_3	0·80	1·10	2·70	1·10
CaO	0·10	0·30	3·35	1·90
MgO	Trace	Trace	0·05	Trace
FeO	5·73	4·47	—	—
Fe_2O_3	13·62	19·03	2·51	1·27
Mn_3O_4	0·29	0·28	0·19	0·20
	100·14	99·94	99·80	99·77

[1] The greater part of the work in connection with this paper was done last year. Mr. C. S. Graham, of Scunthorpe, had made a similar investigation, the results of which were published in *The Iron & Coal Trades Review* on 6th December, 1918. The results obtained by Mr. Graham, Mr. Rengade and myself all confirm the same thing.

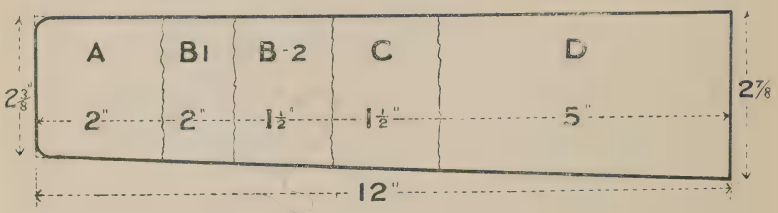
Brick from Basic Open-Hearth Furnace.

	A.	B.	C.	D.
SiO_2	89·00	88·80	91·00	97·30
Al_2O_3	0·80	0·70	1·80	0·70
CaO	3·90	3·85	4·20	1·15
MgO	0·65	0·72	0·10	Trace
FeO	0·75	0·50	—	—
Fe_2O_3	3·59	4·39	2·56	0·48
Mn_3O_4	1·11	1·00	0·52	0·14
	99·80	99·96	100·18	99·77

The brick from the Cargo Fleet furnace having served its full life had the following dimensions after use:

After being taken from the furnace roof:

Approximate Measurements:



Before being put into use the dimensions were stated to be:

12 in. × 6 in. × 3 in.

For the purposes of comparison the brick has been divided into zones, the analyses of which are as follows:

	Zone A.	Zone B1.	Zone B2.	Zone C.	Zone D.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
SiO_2	92·20	89·17	88·20	87·85	95·50
TiO_2	0·07	0·19	0·25	0·28	0·10
Al_2O_3	0·76	1·12	1·78	1·55	1·19
Oxides = Fe_2O_3 ..	4·57	5·64	4·07	4·07	0·71
CaO	1·80	3·00	5·00	5·50	2·00
MgO	0·21	0·47	0·36	0·45	0·14
Alkalies, etc... ..	0·39	0·41	0·34	0·30	0·36
	100·00	100·00	100·00	100·00	100·00
Sp. gr. brick powder..	2·338	2·393	2·390	2·468	2·451
Fusion point	1595° C.	1580° C.	1610° C.	1610° C.	1710° C.

(7·34; 10·23; 11·21; 11·57; 4·04)

Photo No. 1.

The following is a description of the respective zones. (See photo No. 1.)

Zone A is the lower layer, 2 inches in thickness, and is that which had been heated to the highest temperature A freshly made fractured surface appears to be quite homogeneous but vesicular, and is correctly described by Mr. Rengade. It is light grey in colour and closely resembles the fracture of grey blast-furnace slag. The brick was cracked at the junction between zones A and B, due probably to strain when in the heated condition. Zone B1, 2 inches in thickness, is of a much darker colour than zone A, but is free from unabsorbed quartz. Zone B2, $1\frac{1}{2}$ inches in thickness, is similar to B1 zone, but contains a considerable number of particles of unabsorbed quartz. Zone C, $1\frac{1}{2}$ inches in thickness, has a light yellow matrix in which are embedded unabsorbed particles of quartz. Zone D corresponds closely with the appearance of the original brick: it extends from zone C to the outside of the brick, a distance of roughly 5 inches.

Microscopic Examination.

A description of the microscopic structure of thin sections from the various zones is accurately and correctly given by Mr. Rengade, whose remarks and observations are repeated hereunder:

The microscopic examination, in polarized light, of thin sections cut from the aforesaid zones reveals in zone B the frequently described structure composed of large transparent tridymite crystals: the joints between these crystals are filled with a black, opaque substance. In zone A it is noticed that the tridymite has undergone actual fusion, the large crystals being replaced here by spherules surrounded by, but not mixed with, the black opaque constituent. On cooling, the molten tridymite changes into cristobalite and, in some places, forms birefringent regions of badly developed tridymite. In zone C the large tridymite crystals continue to appear, but gradually diminishing in size and numbers according as the less heated sections are approached, until in zone D the normal structure of the original brick is again encountered.

Judging from the analyses it is quite obvious that floating particles of iron oxides, lime, etc., have been absorbed at the lower surfaces of the bricks. The interesting feature is that most of these bases, after combination with some of the silica of the bricks, have ascended by capillary attraction to a distance exceeding 5 inches.

The maximum amount of iron, it will be observed, is in B1, and the maximum of lime is in zone C.

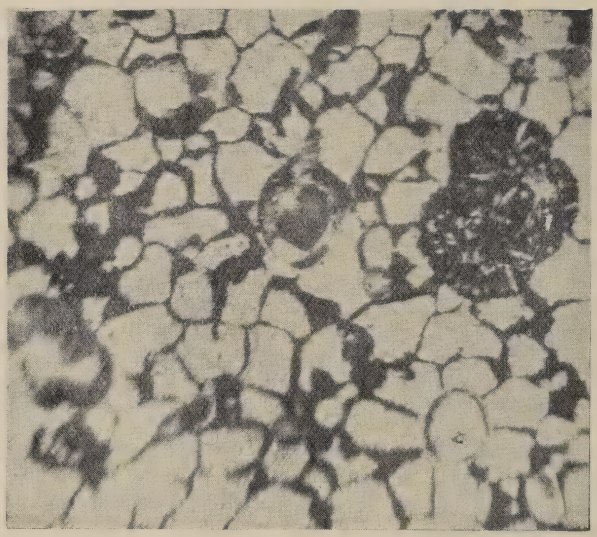


Photo No. 2.

Fusion Points.

It will be noted that whilst the fusion point of the material corresponding to the original brick is 1,710° C., that of zone B1 is about 130° lower. There is very little difference in the melting point between B2 and C, but both are lower than that of the original brick zone D. Concentration of the iron and lime by capillarity from the hot end of the brick is responsible for this. Zone A, which one would have expected to be more fusible, is actually less so than zone B above it.

Density, etc.

The specific gravities and porosities of the various zones were determined, with the results indicated below:

	A.	B1.	B2.	C.	D.
Specific gravity of brick	1·978	2·040	2·108	2·170	1·777
Specific gravity of brick powder...	2·338	2·393	2·390	2·468	2·451
Porosity by powder method ...	15·40	14·80	11·80	12·10	27·5

Judging from the appearance of the brick itself it would not appear that there had been any serious changes in volume. As, however, the porosity in B and C zones is considerably less than the porosity in D, this difference is obviously due to the filling in of the original pores by the liquid silicates that ascended by capillary attraction.

General Conclusions and Comments.

The evidence given above indicates:

1. That the fusible silicates formed at the surface of the brick exposed to the flame of the furnace, after combination with the floating oxides of iron and calcium, etc., to a large extent flow upwards into the cooler but still highly heated portions of the brick by capillary attraction and become concentrated at a considerable distance from the point where they entered.

2. That the lime absorbed from the floating dust and a portion of the original lime in the brick and the alumina together with some iron oxide, together with some of the silica of the brick, constitute the fusible silicate that flows upwards, leaving the most highly heated portion of the brick with less lime and alumina than was present in the brick originally. In other words, so far as lime and alumina are concerned, the brick has become purified by the elimination of a portion of these bodies.

3. The iron oxides are at a maximum in zone B about 2½ inches from the hot end, but a considerable quantity, 4·57 per cent., has remained in zone A where the brick had been close to its melting point. The very refractory iron silicates remaining is located in the form of cell walls surrounding the particles of tridymite. (See photo 2.)

4. The porosity of the brick in the zones A, B and C is greatly reduced owing to the space being filled by the fusible silicates, that which ascended by capillary attraction.

5. The specific gravity of the brick at zone D corresponds closely with the average of standard silica bricks, being 1·77 against 1·75.

6. The actual fluxing away of this brick at the hot end was remarkably little, as is shown by the sketch.

7. The conclusion is obvious, that as the bricks are shortened in length, during service, by the fluxing action of the floating dust in the furnace, the fusible silicates at first concentrated in zones B and C will move upwards, and B zone will become A zone and C zone will become B. As the fusible silicates ascend upwards from B the fusing point will be raised when it passes to the composition of zone A, a most beneficent

arrangement, for, if the flux remained in zone A and did not ascend, the bricks would more rapidly melt away and their life be greatly reduced.

8. The question naturally arises, is porosity essential and advantageous, and if so, what is the ideal porosity? In the brick under consideration the porosity was 27·5 per cent., which corresponds closely with that of standard bricks, which varies between 27 per cent. and 30 per cent., and has an average of 28·5 per cent.

9. Judging from the fact that the zone A must have been quite coherent it is evident that the ferruginous silicate surrounding the silica grains could not have been in a freely molten condition, otherwise that portion of the brick would have been simply broken up and fallen into the furnace. Photo No. 2 clearly shows the cristobalite surrounded by the ferruginous silicate. As silica melts at 1,750° C., and as the temperature at zone A must have been near 1,700° C., we must assume that the silicate was not quite fluid at that temperature.

10. Fused silica in powder has a specific gravity of 2·196, so one may conclude that the independent particles of silica in zone A have been completely changed to tridymite, for the powdered material of that zone is 2·338 compared with 2·451 of the powder of zone D, and 2·45 of that of average silica bricks.

11. It may be accepted in general terms that this investigation confirms in every particular that of Mr. E. Rengade.

Bearing on the effect of heat upon silica bricks a most important paper by Prof. H. Le Chatelier and B. Bogitch appeared in the *Bulletin de la Société de l'Industrie Minerale* 3e livraison de 1917, page 49, and was submitted at the Milwaukee meeting of the American Institute of Mining Engineers, October, 1918. This paper should be read by all interested in the subject, as it clearly shows the changes in physical properties which take place in silica bricks at various temperatures.

I am indebted to my assistants—Mr. E. W. Jackson and Mr. A. Scholes—for the analytical and pyrometrical work referred to in this note.

DISCUSSION.

Mr. H. E. WRIGHT (Messrs. Dorman, Long & Co., Ltd.): —A considerable time ago Dr. Stead mentioned to me the results which had been found upon the altered texture of silica brick by the distinguished French expert, and that in the experiments he had made, which he has placed before us to-day,

he had verified the truth of the statements, and that he was going to place this verification before the Middlesbrough Meeting of the Ceramic Society, and would like me, in going round our various steel works to look into the matter with a view to confirming his results. Of course, to anyone like myself, knowing the great care which Dr. Stead exercises in all scientific investigation, it seemed quite unnecessary to talk about such confirmation, but I have convinced myself there is no doubt of the case being exactly as Dr. Stead has put it. Furnace roofs are sometimes burnt down, and sometimes fail from other causes, but when they run their full life, according to my observation at our various works, nine out of ten of the bricks taken from the old roof show exactly what Dr. Stead has stated to-day, and I have no need to give analyses as the analyses differ only in minor points from those already stated. With Mr. Weldon Hanson I quite agree in thinking that one of the chief things causing this is not dust but slag spray, although I have never estimated phosphoric acid in the bricks as he has done. I think that it was quite unnecessary for Dr. Stead to offer any apology for placing this paper before us. I know that he spoke to me of the confirmation of the results and placed the facts before me before the article was published in the *Iron and Coal Trades' Review*, and I think our thanks are due to Dr. Stead for this investigation, because it is only by a clear understanding of the actual things which happen that any true progress can be made, and anything tending to knowledge which will help to improve the life of our steel furnace roofs is a matter of such great importance, that such benefits would be derived from the result, that any information in the direction must be valuable and should be placed on record. One of the speakers mentioned increasing the lime in the bricks. This, in my experience, would not lead to benefit in high grade silica bricks where over 2 per cent. generally leads to trouble. It is also precluded by the fact that the best bricks are generally over 95 per cent. silica and, as to my mind, increase in this direction offers up the greater prospect of improvement. I was much impressed by Dr. Scott's statement of experiments, and hope that these will be carefully studied with a view to getting bricks, if possible, higher in silica content.

Mr. J. H. WHITELEY:—I think Dr. Stead's plan of dividing the used roof brick into five zones instead of four, as was done by Rengade, is much to be preferred. Some time ago I tested a used brick from the roof of an acid furnace by dividing it into four parts and analysing each part separately.

The variations in the lime content were much less pronounced than those given by Rengade. The results were as follows:—

Zone A (grey)	..	lime 0·35 per cent.
,, B (black)	..	,, 1·10 ,,
,, C (yellow)	..	,, 1·85 ,,
,, D (reddish)		,, 1·70 ,,

I noticed, however, that between zones B and C there was a narrow strip which had a decidedly greenish tinge. I therefore tried again on another similar brick, this time dividing it into five zones as shown by Dr. Stead. The lime contents were as follows:—

Zone A	..	..	0·40 per cent.
,, B1	..	..	0·70 ,,
,, B2	..	..	3·80 ,,
,, C	..	..	1·80 ,,
,, D	..	..	1·50 ,,

The large increase in lime in greenish-coloured zone B2 was accompanied by an increase in iron oxide and alumina, and this confirms the evidence so far obtained by Dr. Stead, Rengade and others, that the lime travels up the brick along with iron oxide and not in advance of it.

There is much evidence to show that the iron oxide diffuses into the brick in the form of a molten cinder containing silica in solution. The mixture having the lowest freezing point, *i.e.*, the eutectic between iron oxides and silica, will consequently penetrate the farthest into the brick. Now the presence of another constituent such as lime will still further lower the freezing point of the eutectic, and as a result the limit of penetration will have the highest lime content. Lime has therefore a beneficent action in helping to remove the accumulating foreign material from the hottest zone, and it would seem possibe that a higher lime content might actually help to lengthen the life of a roof brick.

Mr. WELDON HANSON:—The bricks described by Dr. Stead are similar to some I examined some years ago, and, as they are a rather familiar sight in all open-hearth steel works, no doubt a lot of my brother chemists will have investigated the matter at one time or other. The only difference between Dr. Stead's analyses of the different zones and mine is that I found a considerable amount of phosphoric acid in zones A, B and C, viz.:—

Zone A	..	..	1·04 per cent.	P_2O_5
,, B	..	..	1·52 ,,	,,
,, C	..	..	0·76 ,,	,,
,, D	..	..	Nil	

I need hardly say that my tests were on bricks from a basic furnace.

In a steel furnace during the "boil" there is a considerable amount of slag spray flying about, a great part of which is carried by the gases against the block ends, and this, in my opinion, is one of the chief causes of the excessive wear of this part of the furnace. A smaller quantity of spray reaches the roof and walls and is melted and absorbed by the bricks. I think this spray is the source of the extra lime and iron found in the burnt bricks and not "floating dust" as mentioned by Dr. Stead.

The brickmaker is up against the tough problem of making a brick to stand up against this cutting action of the slag spray.

Mr. BAINBRIDGE:—I have much enjoyed Dr. Stead's paper and think it of great interest to the users of refractories.

There is only one point to which I want to refer. In conclusion No. 7 on the last page of the paper, mention is made of the upward movement of zone A as the brick is fluxed away.

Recently I was able to examine a patch of roof removed from a Wellman basic open-hearth tilting furnace, the patch being taken from an area close up to the port end.

The bricks had been originally 12 in. × 6 in. × 3 in., but the bulk of them on removal were only 7 to 9 inches long. The majority of these showed a complete absence of zone A and only in a few cases was this zone to be seen.

We selected one of these latter bricks and had a rough analysis made as follows:—

	Zone A.	B.	C.	D.
	Length $\frac{5}{8}$ in.	$2\frac{1}{4}$ in.	$2\frac{1}{2}$ in.	3 in.
Al_2O_3	2·73	2·40	2·05	0·94
Iron oxides as Fe_2O_3 ..	4·57	3·50	3·30	0·86
CaO	8·15	6·25	6·40	2·50
MgO	0·18	0·07	0·18	0·14
Total bases ..	15·63	12·22	11·93	4·44

Approximate ratio of bases being A, B, C, D; $3\frac{1}{2}$, 3, 3, 1.

In view of Dr. Stead's confirmation of Mr. Rengade's results I conclude that the position of the brick in the furnace and the direction of the gas flame must influence the rate of fluxing to such an extent that in some cases the brick is worn away quicker than the oxides can pass into the higher part of the brick, or else its position is such that the fume or dust is deposited on the face quicker than it can pass into the higher

zones, also as the brick wears away, the outside air, cooling the thinner brick, will prevent the fused silicates passing upwards.

Dr. STEAD wrote:—He was glad there had been such a good discussion. He agreed with Mr. Whiteley that what diffuses upward in the silica bricks is in a liquid form and consists of iron and lime silicates, and probably is eutectic in character.

Mr. Weldon Hanson's experience on testing bricks from the roofs of basic open-hearth furnaces confirmed that of some other investigators with regard to the presence of phosphoric acid. It is obvious that when this is present it must have got there *via* projections from the basic slag, and not from the dust floating in the burning gases. He had since the meeting examined the zone A of the brick from the Talbot furnace and had found only 0·16 per cent. phosphoric acid.

XXIII.—Seasoned Silica Brick from Roof of a Basic Open-hearth Furnace after 135 Charges.

By C. S. Graham (Scunthorpe).

THE three modifications of silica important in this connection are quartz, tridymite and cristobalite. Each of these three has α and β phases, and each can be converted into either of the others by appropriate heat-treatment. At ordinary temperatures α phases exist which pass into β phases as the temperature rises. These transformations are rapid, whilst the transformation of one mineral into another is as a whole very sluggish, especially near the inversion temperature. The principal inversion temperatures, according to Fenner,[1] are as follows:—

575° C.	Inversion of	α-quartz to β-quartz.
870° C. ± 10	„	β-quartz to β_2-tridymite.
1,470° C. ± 10	„	β_2-tridymite to β-cristobalite.

Cristobalite may also develop as a metastable intermediate phase below 1,470° C.

Work done by Professor Le Chatelier, and independently by Dr. A. Scott[2] proves conclusively that the stability relations, particularly of tridymite and cristobalite, are still in doubt. Table I gives the specific gravity and indices of refraction of the above forms of silica.

Table I. Specific Gravities and Indices of Refraction.

Composition	Specific Gravity	Authority	Index of refraction	
			α	γ
α-Quartz ...	2·65		1·544	1·553
β-Quartz ...	2·633			
α-Cristobalite ...	2·33	Endell ...	1·484	1·487
	2·333	Artificial cristobalite ...		
		Fenner ...		
	2·34	Natural cristobalite ...		
		Mallard ...		
β-Cristobalite ...	2·21			
α-Tridymite ...	2·32	Endell ...	1·469	1·473
	2·27	Artificial tridymite ...		
		Fenner ...		
	2·28	Natural tridymite ...		
		Mallard ...		
β-Tridymite ...	2·32			
Quartz glass	2·21	Dana, Endell ...		
	2·194	Schwartz ...		

The specific gravities in Table I show that during burning a certain expansion takes place. This permanent expansion, which is of vital technical importance, must not be confused with the temporary expansion. The latter, being the expression of the coefficient of expansion of silica, is unavoidable, and will disappear on cooling.

Quartz, tridymite and cristobalite are most conveniently identified by estimating their indices of refraction by the immersion method. According to Fenner,[3] these indices are:—

	Mean index of refraction
Quartz	1·549
Cristobalite	1·486
Tridymite	1·471
Calcium silicates[4]	higher than that of quartz

Specific gravity determinations are of little value for discriminating purposes, the reasons being:—(1) small difference between specific gravities of tridymite and cristobalite; (2) some converted grains have a core of unconverted quartzite; (3) products are invariably filled with microscopic cracks causing a low specific gravity result; (4) irregular distribution of impurities, such as ferric oxide (specific gravity 5·2) and alumina (specific gravity 4·0).

Quartz may be readily distinguished from tridymite and cristobalite by its higher refractive index and double refraction. Between crossed nicols it may also be identified by its interference colour, which is generally yellow, in contradistinction to the grey of tridymite and cristobalite. Tridymite may be recognised by its low refractive index, low double refraction, its characteristic needles, and by the lath-shaped and wedge-shaped outlines of its crystals. Between crossed nicols it gives grey as interference colour. It also occurs as aggregates of overlapping, pseudo-hexagonal plates arranged similarly to tiles on a roof.

The double refraction of cristobalite is generally so low as to be invisible except with the aid of a sensitive (selenite) plate. Tridymite and cristobalite may be identified by studying a portion of the powdered material, immersed in a liquid of about 1·48 index of refraction, which is intermediate between the mean indices of tridymite and cristobalite. By the use of the thermal microscope, Endell found that cristobalite becomes isotropic at 225° to 230° C. The change in volume of cristobalite at 230° is considerable, consequently mercury dilatometer observations offered a sure way of distinguishing cristobalite from tridymite. A specimen of silica brick composed entirely

of cristobalite on heating gave the curve shown in Fig. 1.[5] This method of differentiating between tridymite and cristobalite was used by Rieke and Endell, who have gone into this subject with great care.

The wear and tear of silica bricks in basic open-hearth furnaces is to a certain extent due to the abrasive action of the fine basic dust swept through the furnace by the producer gas. Other factors, which also account for this process of denudation, are high working temperatures, local effects of flame, dust in materials charged, liquid metal from bath and charge, and spurting of the slag during boiling of the bath. All these items tend to rapidly promote this fluxing process, which goes

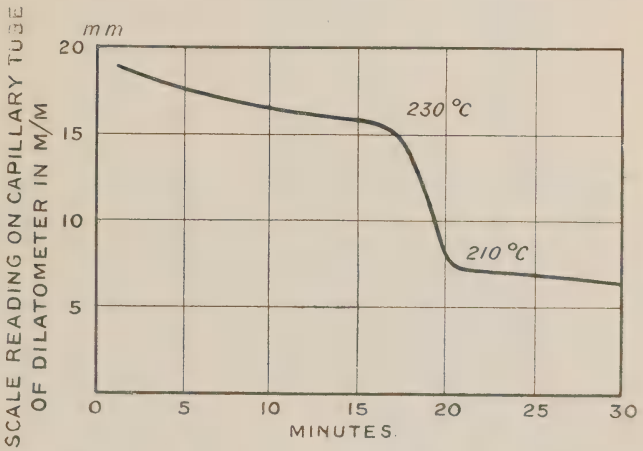


Fig. 1.—Curve showing Effect of Heat on a specimen of Silica Brick composed chiefly of Cristobalite.

on and on, fused material being swept away and fresh surfaces exposed for attack until the bricks are worn away.

Examination of the roof of a 45-ton steel furnace after a run of 135 charges showed that this fluxing process had taken place not uniformly over the whole surface, but somewhat irregularly, the maximum wear being near the transverse centre. The brick about to be described was taken from the transverse centre of the above-mentioned steel furnace. After fracturing at right-angles to the exposed face, four distinct zones were distinguished (Fig. 2).

The colour of the zone exposed directly to the furnace temperature was grey, being followed by a black, a yellow, and a red zone. The grey and black zones were divided by a

distinct line of demarcation, whilst the transition of black to yellow was a very gradual one. From yellow to red there again was a sudden change. After removing skin the different zones were prepared for chemical analysis and specific gravity determinations. Thin transparent sections were prepared by the

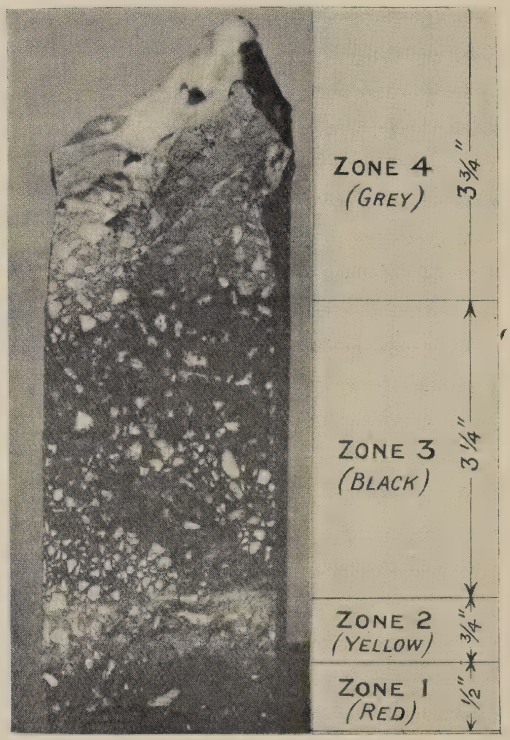


Fig. 2.—Seasoned Silica Brick from Roof of a Basic Open-hearth Furnace after 135 charges.

Zone 4. Length should be $1\frac{3}{4}''$ instead of $3\frac{3}{4}''$.

usual petrological methods for detailed examination under the microscope. The chemical analysis, specific gravity, and porosity of an unused brick from the same batch and of four different zones are given in Table II.

TABLE II. CHEMICAL ANALYSES OF THE FOUR ZONES AND OF AN UNUSED BRICK FROM SAME BATCH FOR COMPARISON.

Zone	Unused Brick from same batch for comparison	1	2	3	4
Depth of Zone		½ in.	¾ in.	3¼ in.	1¾ in.
Colour of Zone		Red	Yellow	Black	Grey
Chemical Analysis—					
Silica	95·0	93·7	91·4	85·5	88·6
Alumina	1·1	1·1	1·8	1·5	1·0
Total iron expressed as Ferric oxide	1·0	1·14	1·52	5·94	5·52
Manganese oxide ...	trace	trace	trace	·27	·37
Lime	2·5	3·19	4·10	6·06	4·04
Specific Gravity—					
Bulk	1·65	1·78	1·80	2·14	2·14
True	2·37	2·41	2·41	2·44	2·42
Porosity, per cent. ...	30·4	26·1	25·3	12·3	11·6

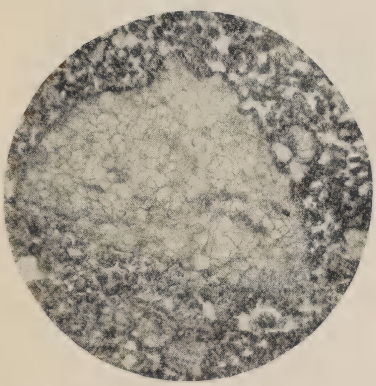


Fig. 3.—Unused Silica Brick showing fragment of quartz rock, with peripheral layer of Cristobalite embedded in darker groundmass. Natural light. x 20

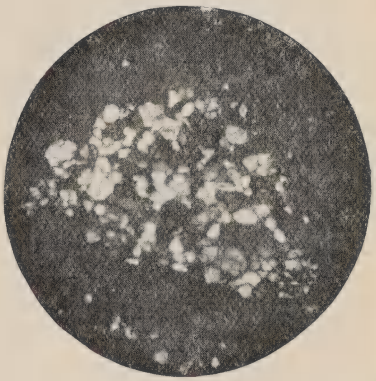


Fig. 4.—Same field as Fig. 3. Between crossed nicols. x 20

Unused Brick (Figs. 3 and 4). Chemical analysis, specific gravity and porosity are normal. Microscopic examination of the thin sections shows numerous angular fragments of quartz rock embedded in a brownish groundmass. Except round the margins, these fragments have generally undergone little change in the kiln Under a high magnification they are seen to consist of a mosaic of small patricles of quartz, closely packed together and separated by thin films which probably consist of ferric oxide and alumina. The groundmass consists of irregular quartz

grains of various sizes set in an unresolvable glassy matrix, consisting of silicates of lime and iron and probably alumino-silicates. The smaller grains have been changed to cristobalite and some of the larger ones are only altered round the rims.

Zone 1 (Fig. 5). The chemical analysis of this zone, which has been in contact with the atmosphere, shows an increase in ferric oxide and lime contents. The specific gravity and porosity have undergone practically no change. Although the life of the brick corresponds to a run of 135 charges, thin sections when viewed between crossed nicols still reveal considerable quantities of unconverted quartzite, which points to the fact that this zone could not have been heated for any length of time above 870° C.—the inversion temperature of quartz into tridymite. The fragments of quartz rock have undergone

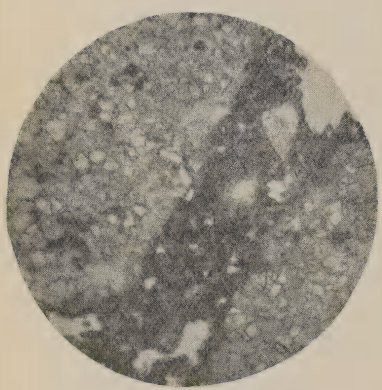


Fig. 5.—Zone 1. Natural light. x 20.

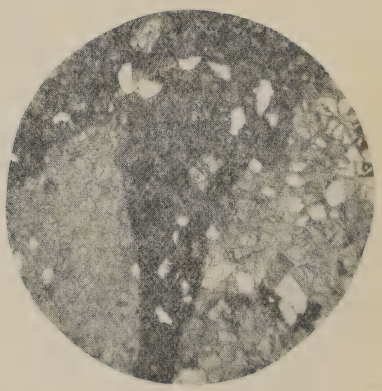


Fig. 6.—Zone 2. Natural light. x 20.

little change, but the groundmass has been altered. Some of the irregular quartz grains have disappeared and have been replaced by very small crystals.

Zone 2 (Fig. 6). The lime, ferric oxide, and alumina contents have increased. This, according to Le Chatelier, is due to ferrous silicates sweeping the silico-aluminate of lime towards the colder end of the brick. Specific gravity and porosity are practically the same as in *Zone 1*. The microscope shows some of the quartz rock fragments to have undergone a change. The peripheral layer of cristobalite in many cases is more pronounced. Unconverted quartzite is still present, and some converted quartzite fragments show an unconverted core. The small crystals in the groundmass seem to have become larger and clearer in outline.

Zone 3 (Figs. 7 and 8). This zone proves on examination to be much harder than any of the others. It is also more refractory and withstands temperature fluctuations without fracture. The exceedingly low silica content is due to the interpenetration of impurities. In the finely powdered sample the magnetic portion could be separated by a magnet. Magnetic oxide is the stable oxide of iron at high temperatures, and does not combine with silica. The bulk specific gravity has increased considerably, whilst the true specific gravity is only 0·03 higher than in *Zone 2*. The reason for this is that the high specific gravity caused by the interpenetration of iron oxides, etc., has been practically counterbalanced by the decrease in specific gravity, caused by the inversion of quartzite (spec. grav. 2·65) into tridymite (spec. grav. 2·27) or cristobalite (spec. grav. 2·33).

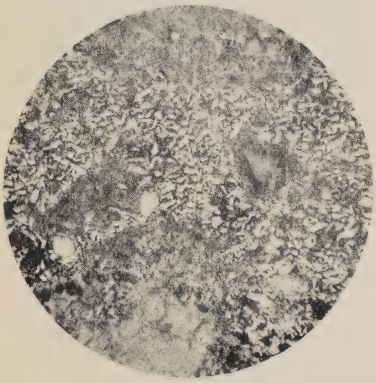


Fig. 7.—Zone 3. Natural light. x 20.

Fig. 8.—Zone 3. Natural light. x 20.

Thin sections show practically complete conversion. Only the very large grains show an unconverted core. The minute crystals which were noticed in *Zone 1*, and which were more clearly visible in *Zone 2*, have grown considerably. This zone consists of a ferruginous matrix, in which are embedded crystals of tridymite and cristobalite. The former occur as well-developed wedge or lath-shaped crystals, which are simply twinned, while the outline of the cristobalite is indefinite. Skeleton crystals of microscopic size are also noticed in the matrix.

Zone 4. This grey zone directly exposed to furnace temperatures has undergone more or less fusion. Blow holes are seen here and there. The low percentage of silica is in all probability brought about either by volatilization of silica or

by the interpenetration of impurities, or by both. Carbon may be indirectly responsible for this volatilization of silica by the intermediate formation of silicon monoxide or amorphous silicon carbide. Microscopic examination of thin sections shows both quartz rock and groundmass completely converted into crystals of cristobalite, which are surrounded by a ferruginous glass. Figs. 9 and 10 are typical microphotographs of this zone.

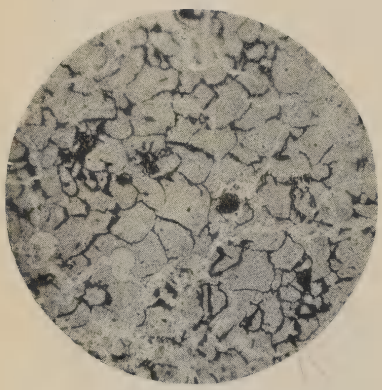


Fig. 9. Zone 4. Natural light. x 20.

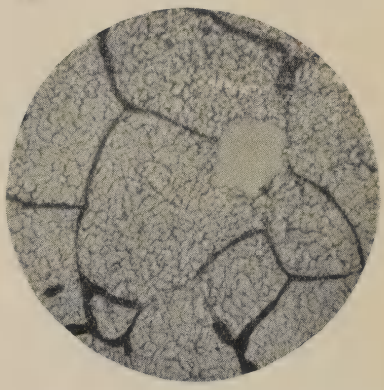


Fig. 10.—Zone 4, Natural light. x 32.

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XXIV.—A New Type of Recuperative Furnace.

By Walter Rosenhain, B.A., D.Sc., F.R.S., and E. A. Coad-Pryor, B.A.

(from The National Physical Laboratory).

In connection with the research work on glass and refractories which has been carried on at the National Physical Laboratory for the past four years, the necessity was early felt for a new type of experimental furnace suitable for glass meltings and for the firing and testing of refractories at very high temperatures, maintained for a considerable time. None of the available types of furnace appeared to meet the requirements of this work, particularly because it was regarded as essential that the furnace should be capable of running for long periods entirely without attention, so as to avoid the necessity for a "night shift" for experimental work. Among furnaces capable of melting down cones 28 to 30, or of attaining temperatures above 1,600° C., there was only a very small choice. Most of these worked with an air blast derived from a fan or blower, and such a plant could not be left to run unattended over night. It thus became evident that a gas or oil-fired furnace, working with natural draught, was the only suitable type, and with a furnace of that kind the very high temperatures desired could only be attained by some method of preheating the air supply. The choice lay between the types generally known as "regenerative" and "recuperative." The regenerative type was at once ruled out on account of the necessity of reversing the valves at frequent (usually half-hourly) intervals, an operation which would require the presence of an attendant throughout the run. On the other hand, existing furnaces of the recuperative type, of which the well-known "Hermannsen" furnace is a good example, did not appear to be readily adaptable for use in small sizes, owing to the relatively large dimensions of the recuperator blocks and the thickness of the walls of the passages through which the interchange of heat takes place.

The authors were accordingly led to design a special type of furnace for their work and, as a result of several successive modifications, they have now arrived at one which

is not only eminently successful and satisfactory for their special purpose, but appears to lend itself to development for many other uses, including its adaptation both to much larger and to smaller sizes than those which they have hitherto constructed.

In seeking to design a furnace capable of yielding very high temperatures, the authors considered that the principal factor must lie in the design and construction of the recuperator or preheater in order that the waste heat of the outgoing products of combustion should be transferred as efficiently as possible to the incoming air (since coal gas was, for reasons of convenience, adopted as the fuel to be used, preheating of the gas was not contemplated). The type of recuperator or preheater adopted, therefore determined the entire design of the furnace. The only form of recuperator which gave promise of affording the desired efficiency appeared to be that consisting of a nest or battery of tubes through which the incoming air is drawn, while the products of combustion circulate about the exterior of the tubes. This type is, of course, well known in such devices as steam boilers, condensers, etc.

The initial and perhaps the principal difficulty in the construction of a recuperator of the tubular type, especially when very high temperatures are to be attained, lies in finding a suitable refractory material of which the tubes can be made. In the authors' earlier experiments a considerable degree of reliance was placed upon the cooling effect of the incoming air, but experience very quickly proved that this did not suffice to protect tubes of insufficiently refractory material. Sets of tubes made of vitreous silica, of the best fireclay, and of "Salamander," rapidly failed in succession, either by breakage or "sagging." Fortunately the authors' research work, dealing with "special" refractories, had already drawn their attention to the remarkable properties of bodies made of silicon carbide made up with various contents of china clay, or good fireclay serving as binder. Tubes made of this material have proved eminently satisfactory, and the initial difficulties of making the tubes have been overcome.

The composition of the tubes has varied somewhat, a larger percentage of clay being permissible in those tubes intended for use in the cooler parts of the recuperator than in those exposed to the products of combustion leaving the combustion space at the full furnace temperature. For the latter position, where the tubes may attain a very high temperature (between 1,400° C. and 1,500° C.) a mixture containing about 20 per cent. of china clay and 80 per cent. of silicon carbide has been found quite satisfactory, although successful tubes have been made with china clay up to 40 per cent. The higher percentages

of china clay only become desirable, however, if the tubes are to be made by a slip-casting process, for which purpose the 40 per cent. china clay mixture is very suitable. Care must, however, be taken to see that a china clay of the most refractory kind is used and that it is not in any way contaminated with foreign fluxes of any sort, as a slight decrease in the viscosity of the binder at high temperatures allows the tubes gradually to sag and fail in service. For the tubes to be used at the colder end of the recuperator the proportion of silicon carbide may be progressively reduced. The tubes can be prepared by slip-casting, moulding or extrusion in any of the well-known ways; if the percentage of china clay is very low the "green" tubes are very fragile, but they become very strong and hard after firing. The tubes are fired up to a temperature of fully 1,500° C., *i.e.*, a temperature higher than that at which they are to be used. This is important, because articles made of silicon carbide exhibit a great tendency to sag or deform (*i.e.*, have a low viscosity) the first time that they are raised to a given temperature. During the firing they must, therefore, be carefully supported, and they must not be used at a higher temperature than that to which they have been initially fired.

The design of the furnace now employed by the authors is the result of a development which has taken place in several steps, and it may be interesting to trace these very briefly.

To indicate the general size of the furnaces to be described, it may be stated that in the first furnace designed for glass-melting experiments the combustion space, intended to accommodate one pot or crucible, was approximately cylindrical, with a diameter of 24 inches and a height (inside) of 18 inches, with a total volume of 4·8 cubic feet and an internal surface of 16 square feet. The general arrangement of this furnace is indicated in the diagram, Fig 1, which shows a horizontal section. The recuperator contained fourteen tubes each four feet long and 1⅛ inches in diameter.

It will be seen that in this furnace the tubes were comparatively few in number and of large diameter, while the products of combustion, passing outwards from the furnace to the chimney, took an uninterrupted course direct from the combustion chamber to the outlet flue, *i.e.*, from points *A* to *B* in the horizontal section, Fig. 1. The result of this arrangement proved to be that the heating surface provided by the recuperator was altogether inadequate, and that, in consequence, the incoming air was not sufficiently heated, while the products of combustion remained too hot and caused undue heating in the chimney. These disadvantages were, to a considerable

extent, overcome in the next modification of the furnace, the arrangement of which is indicated, again in horizontal section, in Fig. 2. The number of the tubes has been increased to 20 and the recuperator lengthened by 13 inches, the diameter of the tubes remaining the same as before.

The course of the products of combustion through the recuperator, however, has now been controlled by the introduction of four baffles, forcing the gases to follow a zig-zag and, consequently, much longer path from the combustion chamber exit to the outlet flue. In this form the furnace gave very satisfactory service, temperatures of 1,550° C. being obtained with ease in the melting chamber, and a large number

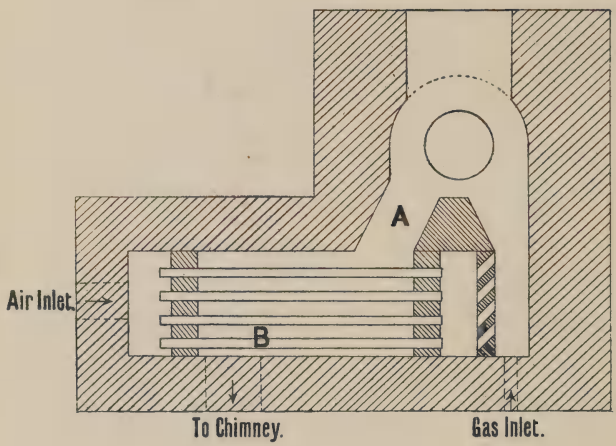


Fig. 1.

of experimental glass meltings have been carried out in it. The furnace could be allowed to run for many hours without any attention whatever, and, provided that the gas pressure and draught remained constant, a very steady temperature was maintained. After a little experience it was possible to set the controls in such a way that the furnace would attain within 50 degrees of the desired temperature in a desired time; such an adjustment could be made in the evening and the furnace found at the desired temperature in the morning.

The general arrangement of this furnace, apart from the recuperator—which has already been described in detail—will be readily understood from Fig. 2. It will be seen that the preheated air leaving the tubes passes into a collecting chamber (*C*), and is then directed by a series of baffles (*D*) into a

mixing chamber (*E*). Here it meets the coal gas, which enters by three horizontal tubes or burners (*F*), the flame is developed in chamber (*E*) and in the space around the pot in the combustion chamber and passes out through the exit (*G*) into the recuperator.

This particular furnace was provided with an opening at the front, through which the pots could be inserted or removed, and a working opening in the roof for manipulating the glass or other contents of the pot.

In the subsequent development of the furnace further changes have been made in the same general direction. These have resulted in the construction now adopted, in which the recuperator tubes are much more numerous and of smaller diameter

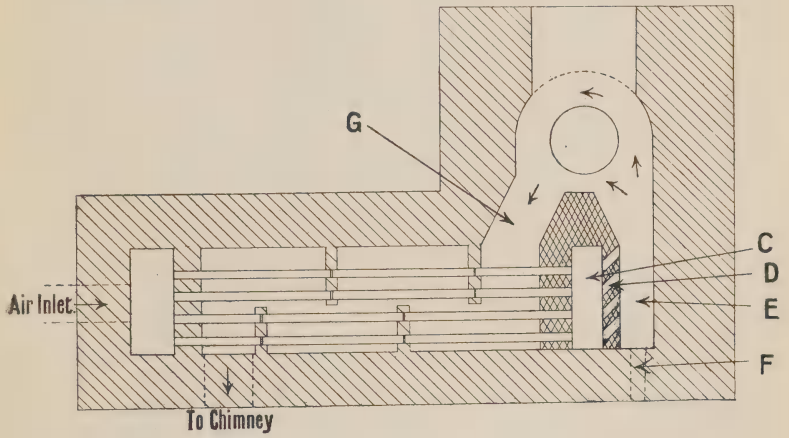


Fig. 2

and of much smaller thickness of wall, while the system of causing the products of combustion to take a zig-zag path by means of baffles has been developed to a much greater extent.

A most successful furnace of this type has been constructed for the purpose of experimental firing and testing of refractories at high temperatures. The working chamber of this furnace has a floor area of 2 ft. 9 in. wide × 1 ft. 6 in. deep, having an arched roof with a minimum height of 20 in., thus giving a total volume of 10 cubic feet. The flame passes across this space horizontally and a very uniform heat is produced, the variation from the inlet end to the exit end being of the order of 20 degrees at temperatures in the neighbourhood of 1,500° C. Temperatures as high as 1,650° C. have been attained.

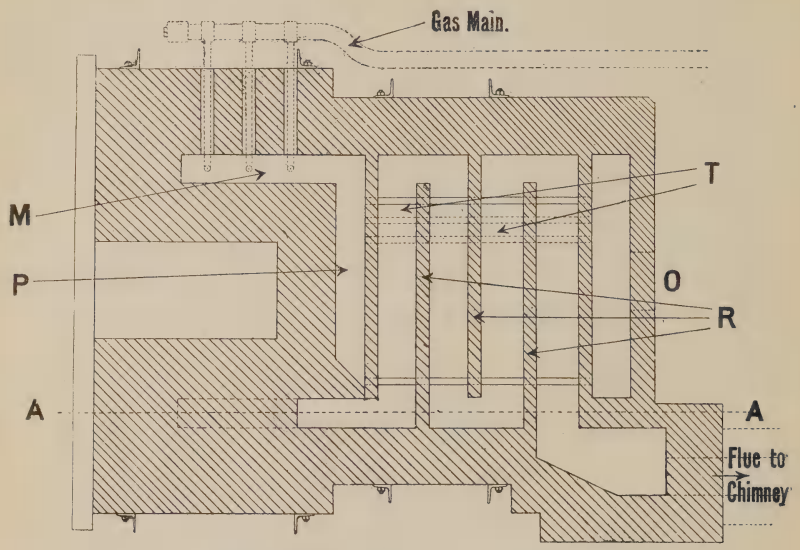


Fig. 3.

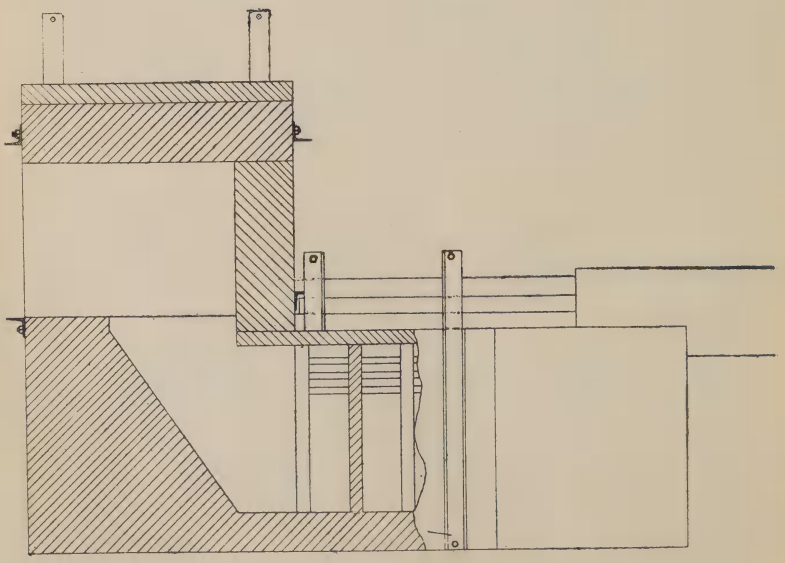


Fig. 4.

The general arrangement of this furnace is shown by means of two sections, in Figs. 3 and 4. Fig. 3 is a horizontal section through the recuperator and mixing chamber, while Fig. 4 shows a part sectional elevation representing a section along the line *AA*, Fig 3.

It will be seen from the horizontal section, Fig. 3, that the air entering at (*O*) passes through the tubes (*T*) into a collecting chamber (*P*), and thence into the mixing chamber (*M*). Here it meets the coal gas which enters through three horizontal

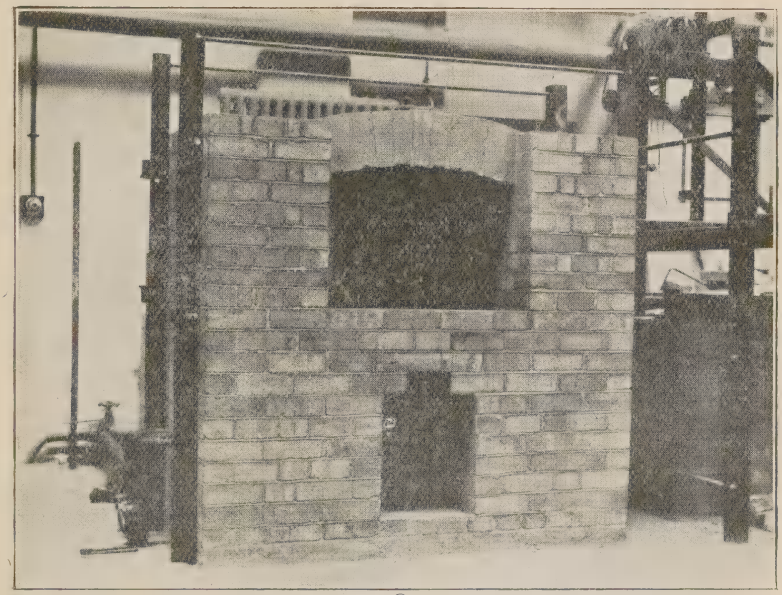


Fig. 5.

tubes. From this chamber, where the flame is formed, the flame ascends vertically into the combustion or furnace chamber proper, which is placed at a higher level than the recuperator. After passing across the combustion chamber the hot gases descend and pass through the recuperator, being forced to take a long zig-zag course by the three baffles (*R*). A general view of this furnace as seen from the front, with the combustion chamber open, is shown in Fig 5. The recuperator, which lies at the back of the furnace, is not seen in this photograph. The arrangement of the tubes and the general construction of the recuperator itself is best seen from the photographs Figs. 6

and 7. It will be seen that the tubes are built up in 8-inch lengths and that the joints are supported in the baffles, these baffles being themselves built up of special shaped firebricks, the shape of the individual pieces being clearly indicated in the photograph, Fig. 7. The recuperator contains nine courses of tubes, each course consisting of thirteen tubes, each tube being made up of four 8-inch lengths.

Perhaps the greatest difficulty which has had to be overcome in the construction of a furnace of this type is the prevention of cracking and breakage of the tubes as the result

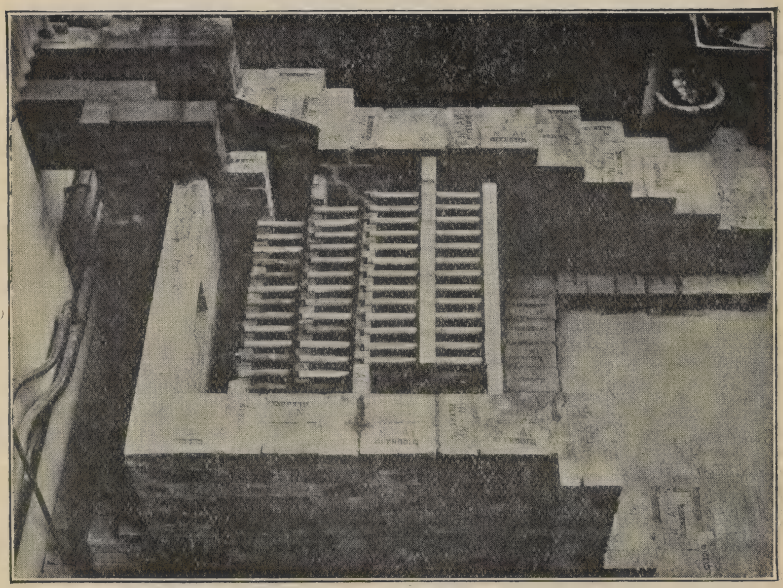


Fig. 6.

of thermal expansion, shrinkage or other movements occurring in the furnace and the baffles. The first effort to secure this was made by endeavouring to leave the tubes as lightly held as possible in the apertures of the baffle blocks. This, however, did not prove entirely successful, and, in the course of time, the furnace suffered from the gradual destruction of the tubes owing to various movements occurring in the baffles. The device finally adopted has been to avoid attaching the baffles to any part of the furnace in any rigid manner. Where they stand on the floor of the recuperator chamber they are placed on a layer of dry grog of a refractory clay which does not

become hot enough to adhere to the baffle blocks. This leaves the baffles free to expand equally in all directions. Anchorage to walls at the sides is also avoided by building the baffles loose and dry into slots formed in the side walls. The amount of leakage through crevices in these slots is very small, as the resistance to the passage of the gases is much greater through these small interstices than around the comparatively open paths which the gases are intended to follow.

So far as experience has yet gone this device promises to solve the difficulty to a very considerable extent and has certainly lessened the breakage of tubes very much. Even without this special device, however, the furnace, from which the illustrations in Figs. 3 to 7 are taken, has successfully

Fig. 7.

withstood 62 heats, in many of which extreme temperatures have been attained. The furnace is still working, but the gradual breakage of tubes, due to the causes indicated above, has somewhat impaired its efficiency.

A second furnace on slightly different lines, again intended for melting purposes, has been constructed quite recently, the improvements in the recuperator construction indicated above having been applied to it with considerable success. A general photograph of this furnace is shown in Fig. 8, in which the recuperator is seen with its covering removed. An interesting feature in the case of this furnace is the provision made for the working opening in the crown of the melting chamber. This has been provided by means of a large circular aperture 14 in. in diameter, in a solid block made of silicon-carbide, measuring, in all, 22 in. × 18 in. × 9 in. This block has been built of wedge shape to fit in to the construction of the arch, and is proving

eminently satisfactory under the somewhat difficult conditions which it is called upon to resist.

In connection with these furnaces, in which, as has already been indicated, very high temperatures are reached, some interesting experiences in regard to furnace linings and materials have been obtained. In the first furnace the lining of the combustion chamber was made of magnesite brick. This proved entirely unsatisfactory, as the brick failed very rapidly in consequence of "spalling." No doubt this was due to insufficient firing of the magnesite during manufacture. The

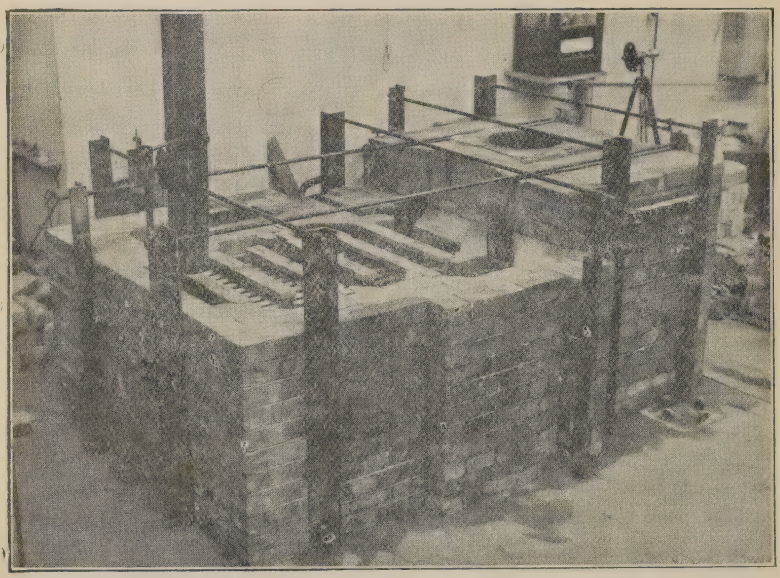


Fig. 8.

magnesite lining was then replaced by one of crude zirconia bricks. These proved eminently successful from the point of view of heat conservation, the gas consumption of the furnace for a standard working temperature of 1,500° C. being decreased from 1,200 cubic feet per hour to 720 cubic feet per hour. A marked diminution in the temperature of the external walls of the furnace in the neighbourhood of the combustion chamber was also clearly evident. This lining lasted rather longer than that of magnesite but failed through much the same cause, viz.: "spalling." Here again the manufacture of the brick was doubtless at fault. The evidence obtained shows clearly that

if a zirconia brick of satisfactory quality can be produced it would materially increase the economy of gas-heated furnaces.

In the furnace illustrated in Figs. 3 to 7, the whole of the combustion chamber has been constructed of a good quality firebrick, but it has been protected by a wash of silicon-carbide made by mixing the powdered carbide with 5 per cent. of china clay, in the form of a slip, and applying this with a brush. In spite of the very high temperature which this furnace has frequently reached, the walls and roof of the combustion chamber, and of the passages leading to and from it, are quite sound after 62 heats. It is, however, necessary, in order to attain this result, to renew the wash of silicon-carbide at comparatively frequent intervals, as, for instance, after 5 or 6 heats. If this is not done, the coating of carbide flakes off, the brick is exposed and the advantage of the carbide coating is lost. For furnaces which are heated intermittently, so that access for repainting is possible, the use of the silicon-carbide wash appears to offer important advantages; in furnaces where the heat is long continued this advantage may not be so great; even then, however, the possibility may be considered of applying the carbide in powdered form while the furnace is hot and the surfaces may be sufficiently soft to allow the carbide to adhere.

The draught used for the working of these furnaces is obtained from comparatively small chimneys, the stacks in both cases being less than 35 feet in height. This draught is found sufficient so long as the furnace is in good condition; sometimes, however, it has been found desirable to accelerate the heating of the furnace, or to attain an exceptionally high temperature, by the application of a forced draught. This has been done by connecting the air inlet of the furnace to a low pressure air supply derived from a fan. This expedient has, however, only been resorted to in quite exceptional circumstances, and the data given as regards gas consumption and temperatures refer to the use of the furnace with natural draught alone.

Some data as to the gas consumption and temperatures attained in various parts of the furnace may be of interest.

In the case of the kiln furnace described in reference to Figs. 3 to 7, the gas consumption, running at a temperature of 1,500° C., is 600 cubic feet per hour of town gas of, approximately, 500 B.Th.U. The air temperature, where the air leaves the recuperator, is between 250° C. and 300° C. below that of the working chamber of the furnace, so that the highest temperature attained by the incoming air is always by that amount lower than the maximum temperature attained by the furnace.

Temperatures attained by the tubes have also been observed. With a furnace running at 1,400° C., it is found that the row of tubes nearest to the furnace chamber attain 1,200° C., the second row 900° C., and the third row 650° C. It will be seen, therefore, that the material of the tubes is not exposed to any excessive temperature, but, on the other hand, the fact that these tubes of comparatively small diameter and thickness are required to bridge a distance of about 7 inches makes it very important that they should have ample power to resist any tendency to flow or sag, and it is probably for that reason that the use of silicon-carbide has been found to be necessary. At the temperatures at which they are called upon to work in these recuperators there is no serious deterioration from oxidation.

It will be readily understood that the very efficient working of a furnace of this type can only be attained by combining with the efficient recuperation which this system affords an accurate control of gas and air supply. The authors have found it useful for this purpose to use a recording instrument giving a record of the carbon-dioxide content of the flue gases, as this has provided a most certain means of securing a proper adjustment of gas and air. This being the case, it will be seen that the atmosphere in the furnace when working at fullest efficiency will be very slightly oxidizing. If a larger excess of air is either drawn into or blown through the furnace, a more highly oxidizing atmosphere can be maintained, but with a corresponding loss of efficiency, so that the furnace will not attain its full temperature. On the other hand, a slight restriction of the air supply will readily produce a reducing atmosphere, which, in this case, is accompanied by a much smaller loss of efficiency.

The authors desire to express their indebtedness to Sir Richard T. Glazebrook, C.B., F.R.S., for his interest in their work.

DISCUSSION.

Mr. H. M. RIDGE:—I have for some years been using a similar design on a much larger scale, and found by actual experience that on large furnaces we can leave our regulating shades for periods of three or four weeks without their requiring any adjustment. These furnaces have decreased labour and supervision to an absolute minimum, while the pre-heating of the secondary air is very satisfactory, and results in a large reduction in the final consumption.

Regarding the tubes, I would like to suggest that the authors might go a little farther than they have done. I am actually

using tubes 27 in. long made of selected fireclays; the cooling by the air protects the tubes from damage by over-heating. Such tubes have been in use for three years and have shown no air or gas leakages.

In reply the AUTHORS said:—It is satisfactory to note in Mr. Ridge's contribution to the discussion that this type of recuperative furnace gives satisfactory results on a works' scale.

As regards the use of clay tubes, we find that this is admissible only for the cool end of the recuperator. The higher the temperature attained by the tubes, and the lower the velocity of the air passing through them, the higher will be the temperature of the air leaving the recuperator and the higher the flame temperature in the furnace, given suitable mixing.

The fact that Mr. Ridge's fireclay tubes are able to remain intact suggests that either he is not obtaining the maximum efficiency (his air is not getting hot enough), or his furnace is running at a lower temperature than the normal working temperature of our furnace. The use of carborundum tubes appears to justify the initial outlay, since, in addition to the increased refractoriness, the high thermal conductivity adds to the efficiency of the recuperative system.

XXV.—Specifications for Refractories for Glassworks' Use.

Communicated, with an introduction, by W. J. Rees, F.I.C., (Dept. of Refractory Materials, University of Sheffield).

REFRACTORIES for furnace construction and for the glass containers—either pots or tank blocks—are a heavy charge in the manufacture of glass. The great extent to which the efficiency and life of a furnace are dependent on the character and behaviour of the refractory materials used is a matter to which, generally speaking, insufficient attention has been given. The information which is at present available is not sufficiently definite to form an adequate guide to manufacturers in their choice of refractories for any given purpose. Variations in practice are considerable, and although in the majority of cases this practice is based on costly experience, there is much room for improvement both in the manufacture of suitable refractories and in their method of use in the glassworks. The introduction of higher temperature furnaces for the manufacture of such types of glassware as chemical and lighting glass, for which this country has been in pre-war days mainly dependent on foreign sources of supply, has emphasised the degree to which efficient production and continuity of working are dependent on the refractories used for furnace construction and potmaking. Systematic investigation into the nature and properties of refractory materials suitable for glassmaking is essential if the industry is to take the fullest advantage of the new conditions. To this end the Society of Glass Technology have appointed a Refractories Research and Specifications Committee,[1] and have initiated a comprehensive scheme of research, the results of which it is intended to embody in a series of full specifications at a later date. As a first step it was decided that it was essential to produce at once a set of provisional specifications based on a combination of existing scientific data with the best practical experience. These provisional specifications, which are subjoined, have, after full

1 This Committee consists of Prof. Cobb, Drs. W. E. S. Turner, M. W. Travers, and J. W. Mellor, Messrs. J. Connolly, J. H. Davidson, S. N. Jenkinson, S. W. Morrison, C. J. Peddle, W. J. Rees, D. Webb, together with Messrs. F. H. Brooke, W. J. Gardner, Major H. C. King, Major C. W. Thomas, Messrs. M. Barratt, H. J. C. Johnston, and A. Stephens, nominated by the Employers' National Council for the Clay Industries.

consideration and discussion, been adopted by the Council of the Society of Glass Technology and accepted by the Committee nominated by the Employers' National Council for the Clay Industries. They are brought forward at this meeting of the Refractories Section of the Ceramic Society with the object of giving those members interested an opportunity to criticise them, to suggest desirable revisions and to generally indicate their views on the subject of research on refractories for the glass industry.

So far as temperature goes, the requirements of the glass industry in refractories are not so drastic as in the steel industry; but greater chemical resistivity is necessary, as the whole of the interior of the pot in a pot furnace, or the entire surface of the tank blocks in a tank furnace, is subject to the continuous action of a molten charge of great chemical activity. The general indications are that highy aluminous clays offer a greater resistance to this corrosion than do siliceous clay. In glasshouse pots and tank blocks, which have lasted well, a considerable development of sillimanite is almost invariably found, and examination of used pots has shown that this protective coating of sillimanite is much more readily formed and retained with aluminous than with siliceous clays. With both pots and tank blocks a low porosity is desirable in the burnt product. With a porous body the rate of corrosion is increased by the penetration of the molten charge, and rapid disintegration may result.

The Committee recognises that all failures of refractory materials in glassworks may not be due to defects in these materials, and is suggesting to glass manufacturers methods likely to obviate failures from defective usage. On the other hand, failures definitely due to unsatisfactory refractories are sufficiently numerous to warrant the hope that all manufacturers of refractory materials for use in glass manufacture will take such steps as will enable them to comply with the specifications. It may be necessary to instal more suitable plant for the preparation of the clays and for their manufacture into pots and tank blocks, etc., but this should not be a deterrent, as it is essential that this country should not lag behind in the provision of the best possible refractories for this important and rapidly reviving industry.

The standardization of sizes and shapes of all glassworks' refractories is a matter which needs immediate consideration. It is unlikely that there is any real need for the great variety in the shapes and sizes of such articles as pots and tank blocks, and a reduction in their number should be advantageous to both the maker and user.

In presenting these provisional specifications for discussion I may say that any criticisms and suggestions will receive the careful consideration of the Committee.

PROVISIONAL SPECIFICATION FOR GLASS REFRACTORIES.

I.—DEFINITIONS AND STANDARDS.

1. The term "provisional" implies that the specifications are intended to be amended as soon as the fuller data on the properties of refractory materials become available. The present specifications are based on the best existing experience of the service which glass refractories should afford. Greater stringency can only be demanded when our knowledge is better defined.

2. The methods of analysis and the tests referred to in these specifications shall, unless otherwise specified, be those drawn up by the Committee of the Ceramic Society on the Standardization of Tests for Refractory Materials, and published in the TRANSACTIONS of the Ceramic Society, 1918, vol. 17, p. 300.

II.—PROVISIONAL SPECIFICATIONS.

TANK BLOCKS.

At the request of the purchaser the following data shall be supplied for his personal information only, together with average samples true to bulk. (*a*) Analysis, showing content of silica, alumina, iron oxide, titanium oxide, lime, magnesia, potassium oxide, and sodium oxide. (*b*) Refractoriness measured by Seger cones. (*c*) Volume porosity. (*d*) Linear contraction or expansion after being heated to a temperature equivalent to cone 14. (*e*) Crushing strength.

Specification.

1. *Refractoriness.*—Cones cut from the blocks shall not be more fusible than cone 30. The test shall be carried out in an oxidizing atmosphere the temperature of the furnace being increased regularly at the rate of 50° C. per five minutes.

2. *Texture.*—The block shall contain no patches of ironstone or other segregated impurity. They shall be uniformly burnt throughout, and if any blue, black or brown core is present, it shall be of the minimum extent practicable having regard to the size of the block. The blocks shall be of regular texture and free from holes and flaws. The arrasses shall be as reasonably sharp as is consistent with the size of the grog

used. All surfaces shall be sufficiently true and plain as to permit of the blocks being walled together without appreciable joint space on the exposed face.

3. *Porosity.*—The volume porosity, *i.e.* (the volume of pores × 100) ÷ volume of piece (including pores), shall not exceed: For flux line blocks 18 per cent., for replacement flux line blocks 25 per cent., for bottom side blocks 25 per cent., for tank bottom blocks 30 per cent.

4. *After-contraction or after-expansion.*—Test pieces (about 3 inches in length and 1 and 2 inches in depth and breadth) taken from any portion of the block after being heated to, and maintained for two hours at a temperature equivalent to cone 14, shall not show when cold more than 2 per cent. linear contraction or expansion. When the test temperature has been reached the furnace shall be maintained constant throughout the test period.

5. *Crushing strength.*—The blocks shall be capable of withstanding a crushing strain of not less than 1,600 lbs. per square inch. The portion of block tested shall be a 4-inch cube and shall have the two ends which come in contact with the jaws of the machine ground or sawn flat and made truly parallel by facing with plaster of Paris in the usual way.

6. *Inspection and testing.*—The purchaser or his representative shall have access to the works of the maker at any reasonable time, and shall be allowed to inspect the blocks before delivery. Duplicate test pieces representative of the bulk of the material ordered shall be selected priory to delivery. The cost of the blocks damaged for the purpose of obtaining test pieces shall be borne (*a*) by the purchaser when the material is proved satisfactory, (*b*) by the maker if unsatisfactory.

Raw Clays and Grog.

1. *Mixture.*—Clay mixture for pots shall consist of at least three portions: (*a*) Bind clay, (*b*) base clay, (*c*) grog. At the desire of the buyer the following data shall be supplied with *samples true to bulk.*

2. *Analysis.*—The analysis shall show content of SiO_2, Al_2O_3, K_2O, Na_2O, TiO_2, CaO, MgO, Fe_2O_3, and the loss on ignition.

3. *Fusion test,* which shall record: (*a*) Squatting temperature, measured by Seger cones, with equivalents in °C and °F. (*b*) Squatting temperature under load in °C. and °F. by standard test to be defined.

4. (*a*) *The bind clay* shall be a fat plastic, aluminous weathered clay. (*b*) *The base clay* shall be a highly refractory

clay. Lumps to be specially selected and hand-picked free from pyrites. (*c*) *The grog* shall be prepared from well-burnt pieces of selected refractory clay. Burnt blocks must show no sign of blue stoning or black core. Nothing of the nature of ordinary firebrick shall be used for grog.

5. A sample of any portion when made up and fired to 1,400° C. shall not show decided speckling due to iron in a segregated form.

6. A fracture of each portion, when made up and burnt to 1,400° C., shall show a dense structure, especially the bind clay. A wide range of vitrification is necessary without signs of over-firing.

7. Clay and grog shall be loaded in clean bags securely tied.

Silica Bricks and Cement.

At the desire of the purchaser the following data should be supplied for his personal information only, with average samples true to bulk: (*a*) Analysis. (*b*) Refractoriness. (*c*) Linear expansion after being heated to cone 12.

Specification.

1. *Composition.*—The bricks shall contain not less than 94 per cent. of silica, and not more than 2 per cent. of lime.

2. *Refractoriness.* Test pieces shall not be more fusible than cone 32 (about 1,710° C.). The test shall be carried out in an oxidizing atmosphere, the temperature of the furnace being increased at the rate of about 50° C. per five minutes.

3. *After-expansion.*—A test piece after being heated to a temperature equivalent to cone 12 for two hours shall not show, on cooling, more than 0·75 per cent. linear expansion.

4. *Texture.*—The bricks shall be uniformly burnt and shall have a regular texture with no holes or flaws.

5. *Variations from measurements.*—All surfaces shall be reasonably true, and there shall not be greater variation than 2 per cent. from any specified dimension.

Silica cement shall in all cases be finely ground and suitable for binding together the bricks for which it is supplied. It shall contain not less than 92 per cent. of silica and shall be capable of withstanding the same test for refractoriness as the brick.

III.—RECOMMENDATIONS AND SUGGESTIONS.

It is to be clearly understood that manufacturers of glass refractory materials are free to adopt any method by which

the materials which comply with the foregoing specifications may be produced. Nevertheless, the Committee believes that some notes, recommendations and suggestions in regard to processes of preparation and treatment likely to achieve improvement in refractory materials may not be unwelcome, and it is in the hope that fruitful results will attend them that the following notes are appended.

1. Tank Blocks.

To Refractories Manufacturers.

(*a*) The Committee suggests that the clay aggregate for tank blocks should usually consist of three portions: (1) Bind clay, which should be a fat, aluminous clay. (2) Base clay, which should be a "strong refractory clay." (3) Grog, which should consist of the bind and base clays mixed together in the finely ground state, tempered and burnt to cone 14.

(*b*) The following composition and properties are suggested as indicating suitable clays:—*Bind clay*: Free silica in small proportions only, and, after burning, alumina 36 to 40 per cent., total alkalies less than 2·5 per cent., total fluxes less than 4·5 per cent. It should have a low sintering temperature but should not be more fusible than cone 31.

Base clay (after burning): Alumina 25–32 per cent., total alkalies less than 1·4 per cent., total fluxes less than 4·0 per cent. It should not be more fusible than cone 31.

(*c*) The following notes are suggestions as to suitable mixtures and methods for the consideration of tank block manufacture.

(i) *Tank bottoms.*—Fat plastic clay 1 volume, lean or strong clay 3 volumes. These clays to be well mixed in the dry ground condition. Grog to be made by tempering a portion of above mixture, making in slabs (say 12 in. × 12 in. × 4 in.) and burning to cone 16. The fired slabs to be crushed in a type of crushing machine producing sharp-edged grains with a minimum of fine material.

Mixture for blocks.—Dry ground clay of above mixture 5 volumes, grog passing $\frac{1}{4}$ in. mesh and held by $\frac{1}{8}$ in. mesh 1 volume, grog passing $\frac{1}{8}$ in. mesh and held by $^1/_{16}$ in. mesh 1 volume, grog passing $^1/_{16}$ in. mesh and held by $^1/_{32}$ in. mesh 1 volume. Those to be well mixed dry, tempered by the addition of the minimum quantity of water, pugged well or treated in a pan mill with the rolls raised and then allowed to mature for one month at least. Blocks to be slowly dried and burned to cone 10.

(ii) *Bottom side blocks.*—Fat plastic clay 2 volumes, lean or strong clay 2 volumes. Grog to be made from above mixture (as for bottom blocks) and burned to cone 12.

Mixture for blocks.—Dry ground clay of above mixture 5 volumes, grog passing $\frac{1}{6}$ in. mesh and held by $\frac{1}{8}$ in. mesh 1 volume, grog passing $\frac{1}{8}$ in. mesh and held by $^1/_{16}$ in. mesh 2 volumes, grog passing $^1/_{16}$ in. mesh and held by $^1/_{32}$ in. mesh 1 volume. Blocks to be burnt to cone 12.

(iii) *Top side (flux line) blocks.*—Fat plastic clay 2 volumes, strong clay 1 volume. Grog to be made by burning above mixture to cone 14.

Mixture for blocks.—Dry ground clay of above mixture 5 volumes, grog passing $\frac{1}{8}$ in. mesh and held by $^1/_{10}$ in. mesh 1 volume, grog passing $^1/_{10}$ in. mesh and held by $^1/_{32}$ in. mesh 2 volumes. Blocks to be burned to cone 14.

(iv) *Replacement (flux line) blocks.*—Fat plastic clay 1 volume, lower grade fat clay 1 volume, strong clay 1 volume. Grog to be made by burning above mixture to cone 6–8.

Mixture for blocks.—Dry ground clay of above mixture 5 volumes, grog passing through $\frac{1}{6}$ in. mesh and held by $\frac{1}{8}$ in. mesh 2 volumes, grog passing $\frac{1}{8}$ in. mesh and held by $^1/_{16}$ in. mesh 2 volumes, grog passing $^1/_{16}$ in. mesh and held by $^1/_{32}$ in. mesh 1 volume.

A suitable lower grade plastic clay should contain when fired: Alumina 34–38 per cent., alkalies not above 3–5 per cent., total fluxes not above 6·5 per cent. It should have a low sintering temperature and should be more fusible than cone 26.

B. *To Manufacturers and Users.*—(*a*) Some defects, in particular, blue-black or brown coring and surfaces which are not plain, are not easy to avoid in large blocks. The Committee therefore recommends the use of tank blocks having no face with an area greater than 4 square feet. (*b*) The Committee recommends the careful storage of blocks in a dry, warm room, with the blocks raised from the floor.

C. *To Glass Manufacturers.*—The Committee recommends that tank furnaces containing new blocks should be raised to the maximum working temperatures and maintained there for at least 12 hours before any molten glass or batch is allowed to come into contact with the blocks.

2. Raw Clays and Grog for Pots.

A. *To suppliers of refractory materials.*—The Committee urges that all care and supervision shall be exercised to see

that the clays used are not contaminated with dirt or other foreign matter. Pans and mills should be thoroughly cleansed before use; where sieve bottoms are used the pans should be swept out every day.

B. *To pot makers and glass manufacturers.*—The Committee believes that sufficient information exists to enable clays suitable for pots to be classified in three grades according to their composition and fusion temperature. The lowest, or grade 3, corresponds to the material in general use; grades 2 and 1 are purer and more refractory.

The following are limits for the composition and fusion temperature suggested in each grade.

Grade 1.

Bind clay.—Chemical analysis: SiO_2, 60 and under; Al_2O_3, 34 and over; Fe_2O_3, 1·8 and under; Na_2O and K_2O, 1·8 and under; MgO and CaO, 1 and under.

Mechanical division: Clay which can be blunged and sieved to pass 80 mesh with not more than 10 per cent. residue.

Fusion test: Squatting temperature, cone 32.

Base clay.—Chemical analysis: SiO_2, 55 and under; Al_2O_3, 40 and over; Fe_2O_3, 1 and under; Na_2O and K_2O, 1·5 and under; MgO and CaO, 0·5 and under.

Fusion test: Squatting temperature, cone 35.

Mechanical division: Ground to pass 80 mesh.

Grog.—Chemical analysis: SiO_2, 50 and under; Al_2O_3, 40 and under; Fe_2O_3, 1 and under; Na_2O and K_2O, 1·5 and under; MgO and CaO, 0·5 and under.

Fusion test: Squatting temperature, cone 35.

Mechanical division: Ground to pass 12 mesh.

Temperature of firing: Not lower than cone 14.

Grade 2.

Bind clay.—Chemical analysis: SiO_2, 65 and under; Al_2O_3, 30 and over; Fe_2O_3, 2 and under; Na_2O and K_2O, 2 and under; MgO and CaO, 1 and under.

Fusion test: Squatting temperature, cone 30.

Mechanical division: Clay which can be blunged and sieved to pass through 50 mesh with less than 10 per cent. residue.

Base clay.—Chemical analysis: SiO_2, 60 and under; Al_2O_3, 35 and over; Fe_2O_3, 2 and under; Na_2O and K_2O, 1·8 and under; MgO and CaO, 0·6 and under.

Fusion test: Squatting temperature, cone 32.

Mechanical division: Ground to pass 50 mesh.

Grog.—Chemical analysis: SiO_2, 60 and under; Al_2O_3, 35 and over; Fe_2O_3, 2·0 and under; Na_2O and K_2O, 1·8 and under; MgO and CaO, 0·6 and under.

Fusion test: Squatting temperature, cone 32.

Mechanical division: Ground to pass 12 mesh.

Temperature of firing: Not lower than cone 12.

Grade 3.

Fired Samples.

Bind clay.—Chemical analysis: SiO_2, 70 and under; Al_2O_3, 25 and over; Fe_2O_3, 2·5 and under; Na_2O and K_2O, 2·5 and under; MgO and CaO, 1·0 and under.

Fusion test: Squatting temperature, cone 28–29.

Mechanical division: Ground to 12 mesh.

Base clay.—Chemical analysis: SiO_2, 70 and under; Al_2O_3, 25 and over; Fe_2O_3, 2 and under; Na_2O and K_2O, 1·8 and under; MgO and CaO, 1·0 and under.

Fusion test: Squatting temperature, cone 30–31.

Mechanical division: Ground to 12 mesh.

Grog.—Chemical analysis: SiO_2, 70 and under; Al_2O_3, 25 and over; Fe_2O_3, 2 and under; Na_2O and K_2O, 1·8 and under; MgO CaO, 1·0 and under.

Fusion test: Squatting temperature, cone 31.

Mechanical division: Ground to pass 12 mesh.

Temperature of firing: Not lower than cone 9.

DISCUSSION.

Dr. W. R. Ormandy:—Having been for a number of years intimately connected with a glass works, where pots of over a ton in weight were used, I have had considerable opportunities of learning a number of points in regard to them. My experience certainly brings me in opposition with many of the points raised in this paper. I am entirely in agreement with the statement that the more highly aluminous clays offer greater resistance to corrosive action, and had I had then the information which I now have, I am perfectly sure that I could have saved that firm very large sums of money. As regards the limit of porosity set down in the specification it was not found that the actual amount of porosity was any accurate measure of the rate at which corrosion took place, but rather the size of the pores was the most important factor. It is perfectly obvious that it is possible to get a similar porosity in two refractories, one with a few pores of relatively large

size, the other with a greater number of smaller-sized pores. From observations made over a lengthy period I came to the general conclusion that the amount of porosity did not matter so much as its form. As regards the author's recommendation that clay mixture for pots should consist of at least three portions I would point out that experience generally has shown that mixture of clays gave the best results. This is, of course, using clays practically as found in Nature. I cannot see why one should not take a single clay whereby the danger of lack of perfect mixture is avoided, and to that extent liability to local corrosion reduced. I do not know of any mixture for making pots which has resulted in the production of an article which failed due to even corrosion over the whole surface.

If the fireclay employed contains pyrites, and most of the best clays do, I think it will be impossible to prevent segregation of the pyritic iron. In spite of the great precautions taken to get perfect admixtures of the clay, pot bottoms were generally found to contain holes lined with silicate of iron.

When we come to examine the specification proposed for the base clays for the manufacture of pots I feel rather sorry for the fireclay producers. There is not the slightest prospect that 5 per cent. of these can ever hope to produce a Grade A clay showing a squatting temperature of cone 35. Until Dr. Mellor told me of their existence I was unaware that there were British fireclays (excluding kaolin) which would stand to this temperature, though I know of a few in Austria and one or two in America.

With regard to glass-pots, if you will start with a good fireclay, and take out of it the fine and coarse sand, pyrites and other coarse impurities, leaving behind practically only clay substance, and will work as your Chairman has explained that they work in France, using a large proportion of grog, properly graded, you will be starting with what is practically pure clay substance, which is homogeneous, and burns exceedingly dense. Such pots will give a maximum contraction at a lower temperature than is now required, and will stand corrosion better than the materials now in use.

It seems to me that these specifications have been drawn up on the basis that we have nothing but natural clays to deal with, and that the whole aspect of the prior treatment of clays with a view to their purification has not been realised, or at any rate not taken into consideration.

Dr. J. W. Mellor:—I think that, unless the proposed specification be much modified, its future will be rearwards. This prognostication is merely an opinion based on what may

be wrong ideas of what a specification should comprise. There is not enough time at our disposal to discuss the matter in detail, but I can indicate two impressions. In the first place, I do not think a specification should hamper progress and unnecessarily immobilize manufacturing processes. It is difficult enough to establish new processes, but it would be doubly difficult if the old processes were entrenched behind a rigid specification. These statements may seem platitudes, but some of the best of processes now in use would be condemned if tested by the proposed specification. In the second place, a specification should not set up impracticable ideals. In some cases the proposed specification unnecessarily postulates a standard too high, and in this I agree with Dr. Ormandy's remarks with respect to cone 35.

Mr. W. J. REES:—As pointed out in the paper, these specifications are *provisional* and will be reviewed in due course. Free discussion cannot be anything but helpful, and the Committee responsible for the drafting of the specifications will take note of the important points raised on this occasion. It is of vital importance to the glass industry that the attention of manufacturers of refractories for their use should be concentrated on the immediate need for an improvement in general quality and durability. If the specifications are too rigid (the suggestions and recommendations are not, of course, an integral part of the specification) then they must be modified in the future, but if Grade A clays *can be obtained*, either in the raw state or by treatment of the raw clay, then the suggestions that they will be available to only a limited number of manufacturers is not of any great importance. To obtain a satisfactory result, co-operation between the manufacturer and user of refractories is essential, and the sympathetic manner in which these provisional specifications have been discussed by the manufacturers is a good augury for future progress.

Dr. Ormandy raises a pertinent point with regard to porosity This had not escaped the attention of the Committee, but to embody such points in the provisional specification would certainly be undesirable and would add to the force of Dr. Mellor's criticism

XXVI.—The Corrosion of Coke Oven Walls.

I.—The Salts Extracted from Coal by Washing.

By W. J. Rees, F.I.C.

(Department of Refractory Materials, University of Sheffield).

A NECESSARY first step in investigating the corrosion of coke-oven walls was the determination of the salts present in the coal as charged into the ovens which would be likely to cause corrosion, and of the salts extracted from the coal in the washing process.

Through the courtesy of Mr. J. H. W. Laverick, of the Tinsley Park Colliery Co., Ltd., Sheffield, I have obtained the average samples of which the analyses are given below. The corrosion of the coke-oven walls at the coking plant of this colliery is comparatively severe, as it appears to be at all ovens in the Sheffield district where deep coals are coked.

The coals which are at present worked at this colliery are:

The High Hazel Seam, at a depth of 120 to 220 yards.

The Barnsley Seam, at a depth of 216 to 316 yards.

The Parkgate Seam, at a depth of 460 to 560 yards.

The Silkstone Seam, at a depth of 540 to 640 yards.

	Water from Pumping Station*	Water in circulation in Washery	Drainage Water from Washed Slack Hoppers
	Grammes per litre		
Total Solids	1·469	2 780	3·290
Lime	0·154	0·095	0·102
Magnesia	0·143	0·108	0·098
Sodium Oxide	0·304	1·078	1·402
Potassium Oxide ...	0·028	0·033	0·038
Chlorine	0·274	0·928	1·180
Sulphuric Anhydride ...	0·480	0·593	0·626
Carbonic Anhydride ...	0·069	0·051	0·044
Iron & Aluminium Oxides	0·002	0·006	0·013
Silica	0·011	0·014	0·018

* This water is pumped from shallow workings only.

PROBABLE COMBINATIONS IN WHICH THE ABOVE INGREDIENTS ARE PRESENT IN THE WATERS.

	Water from Pumping Station	Water in circulation in Washery	Drainage Water from Washed Slack Hoppers
	Grammes per litre		
Sodium Choride... ...	0·451	1·529	1·944
Sodium Sulphate ...	0·149	0·524	0·768
Potassium Sulphate ...	0·052	0·062	0·072
Calcium Sulphate ...	0·243	0·168	0·165
Magnesium Sulphate ...	0·357	0·264	0·261
Calcium Carbonate ...	0·095	0·057	0·062
Magnesium Carbonate ...	0·051	0·041	0·023

SOLID RESIDUES FROM EVAPORATION OF DRAINAGE WATER FROM WASHED SLACK HOPPERS.

Sodium Chloride	60·87 per cent.
Sodium Sulphate	24·67 ,,
Potassium Sulphate	2·20 ,,
Calcium Sulphate	2·58 ,,
Magnesium Sulphate	4·73 ,,
Calcium Carbonate...	2·82 ,,
Magnesium Carbonate	0·87 ,,
Iron and Aluminium Oxides ...	0·61 ,,
Silica	0·44 ,,
	99·79

	Unwashed Slack	Washed Slack as delivered to Ovens
Sodium Chloride ...	0·37 per cent.	0·18 per cent.
Sodium Sulphate ...	0·19 ,,	0·08 ,,

It is evident that sodium sulphate as well as sodium chloride is removed from the coal by washing. The pit water used in the washery contains a good deal of these salts in solution, but it is unlikely that there would be any increase in the dissolving efficiency of the washers by the use of a purer water. There would possibly, however, be a reduction in the quantity of dissolved salts sent to the oven, in the water adhering to the slack, by using a purer water; but it is unlikely that this comparatively small reduction would be worth the expenditure involved in using town's water. The rate of flow of water through the washery is possibly of greater importance as the concentration due to the solution of salts from the coal will be reduced with an increase in the rate of flow, and there will be a corresponding reduction in the salt-content of the water carried into the oven adhering to the slack.

The sodium sulphate present may be a factor of some importance in the corrosion of the oven walls. By interaction with the coal, at the temperature of coking, sodium carbonate will be formed and will be a vigorous corrodant.

DISCUSSION.

Dr. ORMANDY:—Would Mr. Rees give us his explanation for assuming that sodium sulphate would be more corrosive than an equivalent amount of sodium chloride. That common salt would at the temperature of the coke oven dissociate, and that the sodium vapour would corrode the silica in the bricks is obvious. Owing to this dissociation it would tend to act on the whole surface of the brick, whereas the sodium sulphate, being reduced by the carbon to sodium carbonate, would be possibly more local in its action.

Another point which struck me as being of probable interest was the influence of the size of the coal particles. One can assume that the salt is rapidly removed from the surface of the particles, but only comes out from the interior of the particles by diffusion. It seems likely, therefore, that the influence of time in the removal of salt by water washing will be of great importance, and that this time factor will be greatly influenced by the fineness of the grinding of the coal. It would be interesting to learn whether this time factor has been studied and taken into account.

Mr. HANCOCK:—Amongst others we have attacked the problem of salty coal in the course of an investigation at the Imperial College of Science and Technology. It is extraordinary the very slow rate and variable results we can get by washing. At first sight it would appear to be quite possible to get rid of soluble salts quickly by washing with distilled water, but I find that you may go on washing for a very long time and still keep extracting salts. Of course I know it would not be practicable to use distilled water, except for experiments, and the degree of comminution of the coal affects the amount of salt extracted.

With regard to the question of attack I do not know whether Mr. Rees has actually found that sodium sulphate attacks the oven walls, but I see from the proof before me that he says it may be a factor. All washed coal contains a quantity of moisture which undoubtedly seems to act as a kind of vehicle by which the soluble salts are conveyed to the surface of the walls, and this action of water seems to be another point which needs investigation.

Then you have also the question of the reducing conditions which may be present in the oven, so that the whole problem of resistance to attack is one which is extremely difficult and complicated.

I am rather of the opinion, considering the difficulties which one meets with while conducting experiments under conditions which can be controlled with a considerable degree of accuracy, that the success in works' practice is surprisingly good.

It might seem that the problem of salt attack can only be studied effectively at an actual coke oven plant, but personally I am of opinion that experiments on a laboratory scale, where all the conditions can be rigorously controlled and modified as required, are capable of yielding valuable results. On a works modification and control of conditions of experiment cannot be ensured without hampering the output of a plant.

Mr. W. J. REES:—It is not suggested that sodium sulphate would be more corrosive than an equivalent quantity of sodium chloride, attention is simply directed to the point that it may be a factor of importance in connection with the corrosion of oven walls. The localised action of the sodium carbonate formed may produce easily vunerable points for subsequent attack by the products of dissociation of the common salt.

I am in complete agreement with Mr. Hancock in his suggestion that experiments on a laboratory scale, under carefully controlled conditions, are desirable in order to obtain data for subsequent manufacturing scale test work. The economic factor in coal washing must always be kept in view. It is possible on a laboratory scale to effect a more complete removal of the salts, but on the large scale compromises must be adopted. It would be impracticable to spend larger sums on the preparation and washing of the coal than would be saved by the increased life of the oven linings. The problem must be attacked from both sides, but it is likely that the solution must be found in the provision of bricks which will really offer an adequate resistance to corrosion.

XXVII.—The Geology of the Refractory Materials of the North of England.

By J. B. Atkinson, M.Sc., and J. T. Stobbs, F.G.S.

THE increased use of coal and some other inflammable bodies both for domestic and industrial purposes, particularly the latter, has caused a great demand for refractory substances. The North of England may be taken to include the counties of Northumberland, Durham, and Cumberland, and the North Riding of Yorkshire, or what, with the exception of Westmorland, the Furness district of Lancashire and the Isle of Man (from which areas no output of refractory substances is recorded in the official returns), constitutes under the Mines and Quarries Acts the Northern Division.

The North of England contributes its full share of these substances to our national needs, besides exporting considerable quantities. It may be pointed out that in the North of England the smelting of the ores of lead and iron are ancient industries. The earliest application of steam as a source of power was made at collieries in Durham and Northumberland. In these operations the use of refractory materials was a necessity.

The glass-making industry was established on the Tyne about 1619, by Sir Robert Mansell, and towards the end of the 18th century, next to the coal trade, it was regarded as the most important industry there.[1] The selection of the Tyne for this manufacture was doubtless due to the supply of cheap coal in that neighbourhood. The refractories used were probably from the grind-stone post, which is naturally exposed on both sides of the River Tyne.

Probably the first industrial process urgently requiring their use was the smelting of iron in the blast furnace. Firestone was often used for the boshes of these furnaces. When coke became the universal fuel in the blast furnaces in the North of England, firebricks were necessary for the internal lining of coke ovens, and as coking coals very generally repose on fireclays the use of the latter for firebricks soon became common.

Firebricks are said to have been made first on the Tyne about 1764.[2] In 1838, seven million firebricks were made yearly, and in 1863, eighty millions were made in addition to

a large number of retorts.[3] In 1887, 130,000 to 150,000 tons of firebricks and fireclay goods were exported from the Tyne.[3]

Coke ovens were first mentioned as being in use in this district in 1763.[4] Near the close of the 18th century they were in operation in the neighbourhood of Cockfield, in Durham,[5] and no doubt coke-making was carried on in a sporadic way until the inauguration of the railway system.

In 1788, there were 48,200 tons of pig-iron made by the use of coke.[6] The invention of the locomotive gave an important impetus to coke-making, which then became general over that portion of the coalfield which extends from the Tyne southwards, along the western outcrop of the Coal Measures as shown in the map (Fig. 1).

The carbonization of coal for the production of lighting gas was in the early days conducted in retorts made of fireclay.

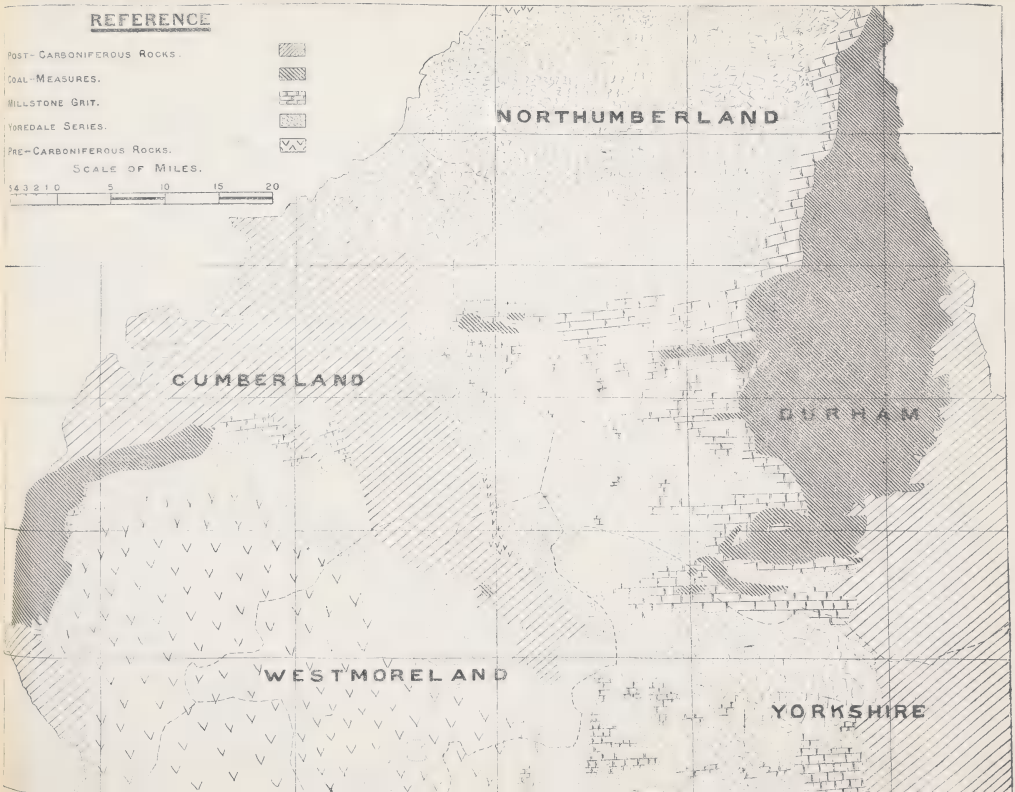
The essential quality of refractory substances is power to resist high temperatures with a minimum alteration in bulk or shape, even under great pressure. Nearly the whole of the refractory substances in the North of England are derived from the Carboniferous System, principally from the Coal Measures; to a less extent from the Millstone Grit and the Carboniferous Limestone Series. Some siliceous rock is obtained from the Estuarine series of the Lower Oolite in the Commondale district of the North Riding of Yorkshire. The Permian Formation of Durham furnishes some dolomite. It may be that the Millstone Grit contains much valuable refractory material, but it has not been much explored.

The following table based on figures taken from returns made under the Coal Mines Act, 1911, the Metalliferous Mines Act, and the Quarries Act, shows approximately the output of refractory substances during the year 1913, the year before the war, both for the North of England and the whole country.

	Fireclay	Ganister	Chert
Northumberland ...	212,321	?	
Durham	314,299	2,139	
Cumberland	45,982	649	
Westmorland	—	?	1,640 (M.M.A.)
N. Riding of Yorks....	—	?	
	572,602		
Rest of British Isles ...	2,013,161		
Total	2,585,763	141,349 (C.M.A.) 170,348 (Q.A.)	

22 per cent. of the output of fireclay for the British Isles came from the North of England. The production of ganister in the area under consideration can only be stated for mines. The greater portion is obtained from quarries, and although in the

Fig. 1. GEOLOGICAL SKETCH MAP OF THE NORTH OF ENGLAND.



Official Returns for the whole kingdom figures are given (as footnotes only) as to the total outputs of ganister from both mines and quarries, the output from quarries for each division is not stated separately.

When one of us was Inspector in charge of the Newcastle district, the production of minerals under the Coal Mines Regulation Act, 1887, in this district was for the years 1902 to 1907 both inclusive allocated to the various geological formation from which they were mined. The Newcastle district included the whole of the counties of Northumberland and Cumberland, but only a portion of the county of Durham embracing about one-third of the coalfield.

The last table for the year 1907 was as follows:—

	Coal	Fireclay	Ironstone	Brick Shale	Ganister	Total
CUMBERLAND—	Tons	Tons	Tons	Tons	Tons	Tons
Coal Measures ...	2,152,402	55,760	252	9,021	1,045	2,218,480
Mountain Limestone	101,388	—	—	—	—	101,388
DURHAM (NORTH)—						
Coal Measures ...	12,688,172	127,670	—	—	—	12,815,842
NORTHUMBERLAND—						
Coal Measures ...	13,168,231	166,501	—	18,059	—	13,352,791
Millstone Grit ...	99	1,743	—	—	—	2,042
Mountain Limestone	55[illegible],499	8,663	—	1,741	—	563,903
Total ...	23[illegible]63,991	360,337	252	28,821	1,045	29,054,446

The fireclays in the Carboniferous Series in the North of England are true stratified beds and have no doubt accumulated under water from débris washed down by rivers. Chemically they are hydrated silicates of alumina with impurities. When free silica is present as in sandy fireclays, their value as refractory substances may not be lessened although the plasticity is reduced; some such clays are often classed as ganisters and have a relatively high value. Ironstone often occurs in the fireclay in the form of balls or nodules, termed by the miner "catheads," and is very deleterious although often capable of removal after the weathering of the clay on the surface.

Ordinary fireclay is of a greyish colour, probably due to some admixture of carbonaceous matter; it is soft and crumbles readily when exposed to the weather. It has a soapy feel. It very generally exhibits curved lines of fracture and is not fissile in planes parallel to the bedding. A. E. N. Arber, in

the *Natural History of Coal*, remarks, "In the Author's experience, an underclay is typically a hardened unstratified 'mud.'"

He probably means that beds of fireclay do not exhibit planes of stratification such as are common in shales and sandstones, but that the bed taken as a whole is stratified cannot be doubted. This absence of evidence of stratification in the beds may be due to changes caused by the penetration of the roots of the aquatic vegetation forming the overlying coal seams or to subsequent earth-movement, and we believe does not apply, at any rate to the same extent, to beds of fireclay not overlain by coal seams. Ordinary fireclays are plastic, and this is a very useful property as it admits of the materials being moulded into the required shape before being burned in kilns.

Beds of fireclay occur in all the three main divisions of the Carboniferous rocks both in the district under notice and other parts of the country. In Scotland the Millstone Grit Series furnishes some of the best fireclays known. In a Presidential Address read by one of us before the Mining Institute of Scotland on the 27th April, 1893, the following table was given.

TABLE SHOWING THE QUANTITIES OF THE DIFFERENT KINDS OF MINERAL RAISED FROM MINES IN SCOTLAND DURING THE YEAR 1892, ARRANGED ACCORDING TO GEOLOGICAL FORMATION.

Geological Formation	TONS OF MINERALS RAISED. Coal	Fireclay	Ironstone	Oil Shale		
Oolite ...	4,622	—	—			4,622
Coal Measures	21,307,081	214,144	297,880	44,726	341 Hone 170 Ganister 7,170 Shale	21,871,512
Millstone Grit ...	3950	249,385	—	—	7,888 Ganister	261,233
Carboniferous Limestone	5,876,020	105,210	574,555	18,572	185,740 Limestone 10,731 Building 700 Shale 624 Ganister 10 Pyrites	6,772,162
Calciferous Sandstone	250	—	—	2,013,778	121,177 Limestone	2,135,205
Old Red Sandstone	—	—	—	—	3 Copper Ore	3
Silurian ...	—	—	—	—	4,044 Lead Ore 128 Zinc Ore	4,172
	27,191,923	568,739	872,435	2,077,076	338,726	31,048,899

This table shows that in the year 1893 the Millstone Grit in Scotland furnished more refractory substances than the other great divisions of the Carboniferous Series.

Fireclay forms the immediate pavement of most of the coal seams not only in the North of England but in other British coalfields, but it may also occur as a band in a seam of coal, sometimes as the roof and occasionally is not directly associated with a coal seam.

A typical section is given below (p. 444) of a shaft at Redheugh Colliery in Durham, about the centre of the Northern coalfield, showing only the position of the fireclays or seggar clays and coals. This shaft was sunk about the year 1875, and it is probable that as it was situated near the principal firebrick district of the North of England, a more careful note was taken of the refractory clays than is usually done during sinking.

Refractory substances such as fireclay and ganister are true sedimentary deposits, and it is not probable that organic or chemical agencies played any considerable part in their original formation, but that they are simply the fine débris brought down by rivers and collected as comparatively pure hydrated silicate of alumina or silica over considerable areas. The beds so formed were afterwards consolidated by the pressure of superincumbent strata, then folded and fractured, and now are found both above and below sea level. As in most other strata, certain changes have taken place in the material originally laid down and these changes may be classed as organic, mechanical, and chemical.

The organic change is principally due to the fact that vegetation, probably chiefly aquatic, flourished on many of the fireclays and some of the ganisters. Beds of both fireclay and ganister very generally subtend coal seams and are penetrated by rootlets from the vegetation that flourished above.

Fireclays are believed by many geologists to represent ancient and exhausted soils. The vegetation has, it is probable, extracted from the clay, compounds of iron and salts of the alkalies and so rendered it more refractory. It is a somewhat striking fact that the fireclays in the steam coal district of Northumberland, unlike those in the coking coal districts of both Northumberland and Durham, are not much utilised.

The main physical difference between the steam coals and the coking coals is that the former are permeated with white spar which fills the vertical facings (or "cleats") as sheets and is sometimes seen as horizontal plates. The body of the steam coal is also mineralised. This alteration is no doubt due to

the downward descent of water charged with mineral matter which was deposited in any open spaces. The coking coals are practically free from the presence of this spar. The effect of the spar appears to be that the steam coal has lost the coking property, is harder and more open burning. It may be suggested that the fireclays in the steam coal area have been similarly affected and their value at any rate is reduced, although fireclay is worked at several of the steam coal collieries the bricks have not the reputation of those from the coking coal districts.

While fireclays occur in all the main division of the Carboniferous Series, ganisters have not been observed in the Coal Measures of the Northumberland and Durham coalfield above the Brockwell Seam, which is the lowest seam of much value. The Coal Measures below the Brockwell Seam are sometimes referred to as the "Ganister Series," a term derived, we believe, from Yorkshire, where ganisters occur in the Lower Coal Measures.

Strata in the Carboniferous Series most like fireclays and ganisters are beds of shale and sandstone, and these latter beds make up the bulk of the thickness, except in some districts where limestones predominate. It may be worth while to consider what is the difference between fireclays and shales on the one hand, and ganisters and sandstones on the other. The first suggestion is that the materials forming the typical fireclays and ganisters are finer than those forming the shales and sandstones, and were therefore carried a further distance out before settling as sediments. Then there are fewer impurities in the fireclays and ganisters than in the shales and sandstones due to the same cause. Shale is known in the coal-mining district of Durham and Northumberland as "blue metal," in the lead-mining districts of the North of England, as "plate." In Scotland ordinary shale is known as "blaes," a term, like blue metal, referring to its colour. It may be noted here that in the mining circles in Scotland shale usually means "oil shale." In the North of England bricks are often made from shale and are usually termed "plate bricks." They are only used for building purposes.

It is somewhat difficult to find records of analyses of ordinary shale, but the late H. Taylor, in a paper "On analyses of rocks of Coal Formation," gives some instructive data which may be quoted.[7]

No. 1.—Fireclay: Sp. gr. 2·519, of a grey colour, streak dull, very soapy to the touch. It constitutes usually the basement of each coal seam. As that

GE

CARBON

NOR

GRINDSTONE SILL

from "Buddles-Hartley" was not a fine specimen, one was taken from the base of the coal at Blaydon Burn Colliery in Tyneside, where it is made use of for the manufacture of firebricks.

Composition.

Water of combination	10·524
Lime	·668
Magnesia	·746
Peroxide of iron	2·008
Alumina	27·753
Potash	2·189
Chloride of sodium and sulphate of soda	·439
Silicic acid	55·500
	99·827

No. 4.—*Bituminous shale*: Sp. gr. 1·860; rests on coarse coal; two or three inches in thickness; black, hard and brittle, of a slaty structure; contains impressions of the flora of the period.

Composition.

Carbon	26·700
Hydrogen	2·630
Oxygen	9·090
Nitrogen	·934
Lime	1·027
Magnesia	·519
Protoxide of iron	4·275
Alumina	19·347
Potash	·839
Soda	·374
Chlorine,	*traces*
Silicic acid	34·276
	100·011

No. 5.—Blue shale (slate clay): Sp. gr. 2·536; in thickness three feet; of a bluish-grey colour; is of a much more earthly appearance than last (No. 4), on which it rests; is softer and not so slaty, and is studded with nodules of ironstone. It is nearly related to the fireclay, both in composition and physical properties.

Composition.

Water of combination	11·083
Lime	0·595
Magnesia	1·377
Peroxide of iron	4·569
Protoxide of iron	4·545
Alumina	23·290
Potash	2·089
Chloride of sodium,	*traces*
Sulphuric acid,	*traces*
Silicic acid	52·452
	100·000

No. 6.—*Micaceous sandstone*: Sp. gr. 2·589, over last (No. 5), varying from 6 in. to 6 ft. in thickness; of a fine white colour, close grained and with small plates of mica, very conspicuously seen.

Composition.

Water of combination	6·888
Peroxide of iron	9·539
Alumina	8·126
Lime	1·112
Magnesia	0·325
Potash	1·655
Soda	1·859
Silicic acid	70·257
	99·761

The whole of the fireclay, with the exception of small quantities of lime and potash, is insoluble in acids. Porcelain clay is hydrated sesquisilicate of alumina represented by the formula $2Al_2O_3.3SiO_2+3H_2O$, and the same composition is found in all our purer clays, and the fireclay of the Coal Formation is also a definite silicate, though not identical with porcelain clay, its composition, setting aside as nonessential the small quantities of lime and potash, corresponding very closely with the formula $Al_2O_3.2SiO_2+2H_2O$.

Comparing the fireclay with the shale, it will be noticed that the proportions of silica and alumina are not very different, the chief difference is in the proportion of iron which in the shale is more than four times that in the fireclay, and probably accounts for the blue colour of the former and would condemn the material as a refractory substance.

It may be suggested that the seggar clays forming the seat earths of coal seams are simply ordinary shales which have been converted into fireclays by the abstraction of iron and alkaline matter by the vegetation which flourished on them, and have changed their colour, and the vegetable growth has obliterated all traces of lamination in the bed, which at the time would be unconsolidated. Turning to a comparison of ganisters with sandstones, the chief difference appears to lie in the ganisters being made up of smaller particles of silica than ordinary sandstones and the cementing material of the ganisters being more highly siliceous than in the sandstones. There are in Durham and Northumberland some sandstones lying high up in the Coal Measures which are called "firestones," and a quarry at Pensher in Durham now furnishes blocks of the stone for the construction of vessels for holding molten glass.

It will be found most useful perhaps to treat the various deposits of refractory material in their stratigraphical order, more particularly those found in the Carboniferous System of rocks, which form the basis of that wonderful industrial development, to which the fame of the North of England is due.

Fig. 3. Firestone Quarry, Pensher, Co. Durham.

FIRECLAYS.

Northumberland and Durham.

Coal Measures.

The names of various deposits of fireclays that have been or are now being worked have been chiefly derived from the coal seams, with which they are intimately associated. There is, however, some difficulty in correlating the several seams which are worked in various districts of this large coalfield. It may seem strange that a question like the correlation of the coal seams of such an important district should have remained so long without a serious attempt having been made for its solution, but such is the case, and under these conditions some of the attempts made by us to define the precise stratigraphical horizon may require correction as a result of subsequent research. Confusion in this question is intensified by the fact that different seams are sometimes known by the same names, and the same seam is often known by different names in different localities.

The interstratification of fireclays and coal seams, in the Great Northern Coalfield, may be seen from the section of the strata sunk through at Redheugh Colliery, which is as follows:

REDHEUGH COLLIERY.

	Ft.	In.		Fms.	Ft.	In.
Coal, Bensham Seam	2	8	at	11	4	8
Bastard fireclay	1	10				
Coal, 6/4 Seam	3	9	at	25	1	6
Seggar clay	3	0				
Coal, 5/4 Seam	3	8	at	29	5	11
Bastard seggar	1	8				
Coal, Hutton Seam	4	2	at	37	4	2
Seggar clay	3	8				
Seggar clay mixed with ironstone...	1	2				
Coal, Cannel Coal		6	at	40	3	0
Bastard seggar	2	6				
Coal, Little Seam	1	6	at	48	2	8
Dark seggar clay	1	2				
Coal		3	at	54	4	11
Grey metal	1	1				
Coal		4	at	55	0	4
Strong grey post, with partings ...	7	6				
Coal, 2 ft. 6 in.)						
Band 7 in. } Harvey Seam	4	1	at	61	5	0
Coal, 1 ft. 0 in.)						
Seggar	2	6				
Coal		9	at	65	2	3
Strong grey metal	2	6				
Coal		9	at	65	5	6
Strong grey metal	2	6				
Coal		9	at	66	2	9
Strong grey metal	7	0				

REDHEUGH COLLIERY—*continued.*

	Ft.	In.		Fms.	Ft.	In.
Coal, Top Busty Seam	2	8	at	75	2	8
Fireclay	3	0				
Coal, Bottom Busty Seam... ...	1	7	at	79	0	8
Fireclay	3	0				
Coal, Three-Quarter Seam... ...	2	0	at	89	0	8
Seggar	2	6				
Coal, 1 ft. 5 in. }						
Band, 2 ft. 4 in. } Brockwell Seam	6	10	at	95	5	4
Coal, 3 ft. 1 in. }						
Seggar	2	8				

The above section embraces all the principal seams of the coalfield except two lying above the Bensham Seam, which in that locality are denuded. It will be noticed that nearly every seam is directly underlaid by fireclay (or, as it is termed, "seggar"), and that only the thin coals are not provided with such a pavement.

Details of Deposits.

Stone Coal Fireclay.—Fireclay from this seam has been worked in the Blaydon district (Blaydon Main Colliery) as far back as 1860. This bed was also worked at Swalwell Colliery by Messrs. Ramsay. Its analysis is as follows:

Silica	72·03
Alumina	24·92
Iron	0·87
Lime	0·96
Magnesia	0·42
Potash and soda	0·82
	100·02

Yard Seam Fireclay.—Trials of this fireclay were made at Deckham Hall Colliery, Gateshead, about 25 years ago. The analysis of the clay was as follows:

Silica	66·40
Alumina	28·54
Peroxide of iron...	2·21
Magnesia	0·43
Potash	1·12
Soda	0·35
	99·05

Five-Quarter Seam Fireclay.—This clay has been worked at several collieries in North-west Durham. That at Deckham Hall Colliery, Gateshead, gave the analysis I in the following

table. The fireclay from this seam at Ramsay's Swalwell Colliery has the analysis II:

	I.	II.
Silica	62·65	79·24
Alumina	29·94	19·40
Peroxide of iron ...	3·21	0·16
Lime	0·31	0·28
Magnesia	1·30	0·19
Potash	2·37	0·69
Soda	0·38	
	100·16	99·96

Lister Seam Fireclay.—This seam was worked near Benwell, where it occurs about 18 yards above the Low Main Seam. The overlying coal was 10 in. thick and the good clay was 2 ft. thick.

Busty Seam Fireclay.—This coal seam is often found in two portions separated by a varying thickness of fireclay parting.

At Whickham the Top Busty Coal is sometimes named the "Stone Coal." The "seggar" here is devoid of stratification and the conical facings, with smooth polished surface, are so common that the miners can foretell the effect of their blasting-shots. In the Brancepeth-Tudhoe district this fireclay used to be largely worked for mixing with that obtained from the Brockwell Seam. About this horizon is the so-called Five-Quarter Coal of Eltringham, whose underclay is worked for firebrick making. Its analysis is as follows:

Silica	66·07
Alumina	21·97
Protoxide of iron	0·77
Lime	0·25
Magnesia	0·43
Potash	1·35
Soda	0·22
Water and carbonaceous matter ...	8·93
	99·99

Brockwell Seam Fireclay.—This fireclay, which forms the floor of the seam, has been extensively worked over an area of 160 square miles. In some districts where the coal years ago has been completely extracted, the ground has in more recent days been reopened, and the old "goaves" (*i.e.*, areas exhausted of their coal) penetrated for the sake of the "seggar." This is notably the case on the banks of the River Tyne, and in the Towlaw-Crook-Brancepeth district. Analyses of this fireclay have often been published. The good clay varies from 1 ft. 6 in.

thick to 2 ft. 6 in. In some places where the bed has been exposed to prolonged weathering *in situ*, *i.e.*, from Glacial times, or perhaps owing to local conditions of deposit, the quality of the "seggar" was quite extraordinary. Such a patch was discovered about 1885, by Mr. J. J. C. Allison, near Old Cornsay Alms Houses. Bricks made of this clay, and used in the crowns of beehive coke-ovens, seemed to be little or no worse after 25 years' work, although the "half-ganister bricks" used under the same conditions would be destroyed in 10 or 12 years. This illustrates the variability of quality due to the local causes in deposits of the same geological horizon, a feature to which attention has already been directed by one of the writers.[8]

In the locality of Crook "half-ganister bricks" were made from a mixture of Busty and Brockwell fireclays, with a proportion of ganister.

Analysis.

Silica	53·90
Alumina	30·04
Protoxide of iron	1·25
Lime	0·33
Magnesia	0·63
Potash	1·48
Soda	0·18
Water and carbonaceous matter ...	12·17
	99·98

Marshall Green Seam Fireclay.—This deposit has been worked in the Witton district near the outcrop. The clay was mixed with a little ganister and made into "ganister bricks."

Millstone Grit Series.

In the North of England this series of rocks is not so sharply defined as in the typical area where the counties of Lancashire, Yorkshire, and Derbyshire meet. Its representative beds are much thinner and their palæontological contents much less known, presumably for lack of resident workers. Owing to the absence of these data, at present it is impossible to determine the relative position of the deposits of fireclay in this series, and the following particulars of these beds are only approximately arranged in stratigraphical order.

In 1903, the Walker Brick Co., Ltd., were working fireclay by a drift at Dipton to the south of Corbridge in the Millstone

Grit. The section is as follows:

	Ft.	In.
Hard rock	1	0
Shale	7	3
Coal		4
White clay	1	3
Fire clay	1	6
Coarser clay	3	6
Sandstone		

The Langley Barony Fireclay Co., at works situated between Haydon Bridge and Allendale Town, manufacture fireclay goods from seggar obtained from a seam in the Millstone Grit, having the following section:

	Ft.	In.
Plate		
Coal	0	3
Black stone		2
Fireclay	4	2

This fireclay is unlike seggar, in that it is more laminated.

Near New Ridley the section of the beds is as follows:

	Ft.	In.
Broken beds and bearing...		
Shale		
Coaly bed		2
Ganister	2	0
Sandstone		

YOREDALE SERIES.

At Bardon Mill a fireclay seam is worked and the section of the associated measures is here given:

	Ft.	In.	
Coal	1	2	left on as roof
Clay	1	8	
Coal		4	
Band		1	
Clay	2	0	
Coal		1	
Clay	2	6	Best
Sandstone ...			

This seam is estimated to lie 30 to 40 fms. above the Little Limestone Coal.

At South Tyne Colliery the fireclay seam is stated to be 40 fms. above Little Limestone Coal, and is approximately at the same horizon as that just mentioned at Bardon Mill. Its section is as follows:

	Ft.	In.
Plate roof		
Coal	0	2
Good clay	2	6
2nd class clay	3	0

At Hook Hill Fireclay Mine, near Corbridge, a fireclay is overlaid by an impure limestone. The clay is sometimes a little mixed with spar and iron in large egg-shaped masses of a black-grey colour. The clay has a limestone roof, and a bed of freestone succeeds this section of ground near Mr. Walker's pottery at Corbridge-on-Tyne.

	Fms.	Ft.	In.	
Blue limestone ...	2	3	0	
Fireclay		5	0	to 6 ft.
Hazle	2	4	6	
Tiger sill	3	0	0	
Plate	7	1	0	
Fireclay		2	0	
Black band			9	
Coal		1	6	
	16	5	9	

The precise geological horizon of this bed is doubtful.

Ganister and Firestone.

It is probable that this highly siliceous rock in this district has long been used in its natural state as a refractory. Ganister rock, generally mixed with fireclay and other materials, for the purpose of making "ganister bricks," would appear to have been first made by Young at Oughtibridge, near Sheffield, about 1858 or 1859.[9] A. L. Steavenson stated that he saw the Young process of ganister brick making about 1858.[10] One of the writers during a school holiday in 1880 got samples of ganister or firestone from several horizons, *e.g.*, Pattinson Sill, Nattrass Gill Hazel, Firestone Sill in the Yoredale Series of the Alston Moor district, for the purpose of trials by grinding and mixing with fireclay for making ganister bricks. About 1883 experiments were made at Tudhoe Colliery with mixtures of calcined flint-and-fireclay bricks, suitable for lining steel furnaces.

Coal Measures.

The highest firestone comes from the rock which was probably the grindstone sill, and is now being worked at Pensher (see Figs. 3 and 1). The main bed of sandstone here is about 70 ft. thick. The firestone bed is about 25 ft. from the top, and it can be obtained in fairly large blocks. It is chiefly used by glass bottle manufacturers to form tanks for holding the molten glass. It is also supplied to steelworks, and for this purpose is crushed into sand.

The "bareing" consists of yellow and blue shale, which is mixed with boulder clay, and manufactured into compact common red brick, for building purposes. The analysis is as follows:

Silica	90·49	Results dried at 100° C.
Alumina	5·38	
Ferric oxide	0·43	Moisture determined by drying at 100° C. = 4·31 per cent.
Lime	0·16	
Magnesia	0·22	
Potash	1·12	
Soda	0·17	Melting point:—
Titanium oxide	0·19	Seger cone No. 34—35
Loss on ignition ...	1·80	Estimated temperature 1,760° C.
	99·96	

The Coal Measures between the Brockwell Seam and the Millstone Grit do not appear to yield ganister, although it is in this series of strata that the famous Sheffield ganister is found. Recently Dr. D. Woolacott[11] has remarked that several beds of ganister have been passed through by a borehole at Sheraton (about 5 miles west of Hartlepool), but whether these were industrial ganister or not is left in doubt.

Millstone Grit Series.

It would appear that very little commercial ganister is available in this series of rocks. From experience in other districts we think that fuller investigation might be justified by the discovery of deposits of this material.

Yoredale Series.

Firestone Sill.—This rock has long been known as a refractory material. N. J. Winch describes it as "a fine-grained sandstone, used for the construction of furnaces and varying from five to six fathoms in thickness."[12]

At Longwitton a ganister is 10 ft. thick and is made up of four layers; it lies about 60 ft. above the Great Limestone, separated from it by a bed of freestone. Analyses of four samples of this ganister here are subjoined:

	1	2	3	4
Silica	99·33	95·83	96·03	96·27
Alumina	0·23	2·11	2·02	2·21
Peroxide of iron	trace	0·39	0·15	0·06
Lime	nil	nil	nil	trace
Magnesia	nil	nil	nil	nil
Potash	0·06	0·16	0·30	0·10
Soda	0·02	0·04	0·03	0·09
Water	0·43	1·27	1·23	1·13
	100·07	99·80	99·76	99·86

All these ganister stones are very rich in silica and are very suitable for making bricks capable of resisting high temperatures. For this purpose the ground material should be mixed with a small quantity of lime for binding the particles together. When used for lining Bessemer converters it will probably be necessary to add a small quantity of ground clay to increase the proportion of alumina, also to bind the particles together instead of lime.

At Oakwood, about a mile to the north of Hexham, there is an outcrop of ganister, whose section is as follows:

Hard white ganister	2 ft. 6 in.
Soft red sandstone	1 ft. 0 in.
Flaggy white ganister (not so hard)...	2 ft. 6 in.

The analysis of the above is as follows:

Silica	98·01
Alumina	1·02
Peroxide of iron...	0·20
Lime	0·18
Magnesia	0·11
Potash and soda...	0·40
	99·92

The "tuft" or "water-sill" below the Great Limestone has been remarked for its siliceous properties by N. J. Winch,[13] T. Sopwith[14] and other early writers. It has been worked at localities scattered over a wide area, from Fourstones on the River Tyne to Stanhope and Wolsingham on the River Wear. Analyses are submitted below:

	Wolsingham.	Fourstones.
Silica	97·31	97·5
Alumina	1·61	1·0
Iron peroxide	0·19	0·2
Lime	0·22	
Soda, potash and magnesia...	0·27	0·8
Water	0·20	0·5
	99·80	100·0

At Fourstones the section is as follows:

Great limestone	30 ft.
Ganister	9 ft.
Plate	12 ft.
Prudham stone	30 ft.

Here the ganister is bedded and the beds vary slightly in appearance.

CUMBERLAND.

In 1883 the annual consumption of ganister in West Cumberland was stated to be 4,000 tons. The Moss Bay Iron Co., in Cumberland, proposed in 1883 obtaining ganister from Amylch in Anglesey. The cost delivered at Workington was expected to be 55 per cent. less than that of the Sheffield ganister.

Coal Measures.

The ganister seam at the Gillhead Colliery, near Maryport, lies at a depth of 52 yards 1 ft., and is 11 yards $2\frac{1}{2}$ ft. above the coal seam known as the Lick Band. It is thus described in the sinking account:

	Yds.	Ft.	In.
Coal		2	0
Dirt			6
Fireclay		1	0
Ganister	1	1	2

The analysis of this ganister (July, 1877) was as follows:

Silica	84·25
Alumina	10·30
Lime	0·95
Magnesia	0·54
Potash	0·79
Combined water	3·00
	99·83

This is a fine white ganister free from oxide of iron; when powdered and moistened it is slightly plastic, and exhibits no sign of fusion when intensely heated.

In the North of England both the Permian and Carboniferous Systems contain dolomite limestones—the Permian so abundantly that it is often referred to as the Magnesian Limestone. Several quarries in the Permian in Durham furnish dolomite which is used as a refractory material.

Of recent years silica rock from the Moor Grit at the base of the Upper Estuarine Series of the Inferior Oolite—a subdivision of the Jurassic System—has been worked near Whitby in the North Riding of York.

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DESCRIPTION OF ILLUSTRATIONS.

Fig. 1.—Map of part of the North of England showing (1) the pre-Carboniferous Rocks, (2) the Yoredale Series, (3) the Millstone Grit Series, (4) the Coal Measures, (5) the post-Carboniferous Rocks.

Scale, 10½ miles to an inch.

Fig. 2.—Generalised section of the Carboniferous Strata yielding refractory material in the North of England; it is largely based on Westgarth Forster's well-known "Section of the Strata" (1st Edition, 1809; Second Edition, 1821).

Scale about 70 yards to 1 inch.

Fig. 3.—Photograph of Firestone Quarry (p. 443) near Pensher, Co. Durham. View looking north, August 6th, 1914.

DISCUSSION.

Mr. J. ALLEN HOWE:—As to the mode of occurrence of the "Moor grit," the name is applied in that district to one of the regular beds in the Estuarine series. It sometimes forms one of the upper strata on the moorland, hence no doubt the local name.

In those Estuarine beds there is a certain amount of vegetable matter, and indeed it is true all over the world that in all sorts of geological formations where you have carbonaceous matter you nearly always have a similar action on the underlying beds. I entirely disagree with the suggestion of Dr. Ormandy that a difference is due to the rock material of which the Coal Measure ganisters are formed; you get the same kind of result in rocks of all ages where there has been carbonaceous matter to influence the modification and translation of the iron compounds during the formation of the deposit.

Mr. Howe asked if Mr. Atkinson could throw any light on the origin of the word "seggar" as on page 439 applied to fireclays in the north-eastern district?

Mr. ATKINSON thought the word was derived from the saggars or large fireclay pots used in pottery districts for holding fine china ware during the process of burning.

Mr. H. M. RIDGE:—In some of the old literature there are references to a high aluminous and very refractory clay in North Cumberland or Durham. I have been unsuccessful in locating the deposit, which would be of interest and value owing to the shortage of such material in the country.

Mr. ATKINSON:—A clay of this nature was worked for some years in the eighties, I think, in Dipton Wood, to the south of Corbridge, in Northumberland.

Dr. J. E. STEAD:—Referring to the North Riding of Yorkshire, I think there is one thing not mentioned—"Moor grit" on the Yorkshire moors. It has entirely different physical properties from normal ganister stones of Yorkshire. I also question the analyses of fireclays.

Mr. ATKINSON said most of them were supplied by the manufacturers and he could not guarantee their accuracy.

Dr. ORMANDY:—I was under the impression that the loss in coking properties of bituminous fuel was brought about rather by the effects of heat and pressure, or was due to the

nature of the original raw materials, as it was closely bound up with the hydrogen-oxygen ratio of the coal, and I fail to see how the presence of the spar can have brought about any change which would result in the loss of coking properties.

Also on page 442 at the foot of the analyses the authors say, "Porcelain clay is hydrated sesquisilicate of alumina represented by formula $2Al_2O_3.3SiO_2 + 3H_2O$. My own experience of the analyses of many hundreds of samples of clay is that the residue after removal of pyrites, free silica and other non-essentials as far as possible is that the clay substance closely resembles kaolinite with the possible difference that the formula may contain $4H_2O$ instead of $2H_2O$. I can hardly credit that the clay substance would have a molecular formula similar to the one quoted.

With regard to the point that geologists are of the opinion that certain clays very free from iron have had the iron salts removed by organic matter, this does not seem likely. That vegetation does tend to remove the iron is certain, but that it will reduce the iron to the almost negligible amount shown in some of the analyses seems to me unlikely.

Mr. STOBBS:—Dr. Ormandy's objection to the probability of the removal of iron salts from some clays by organic matter does not seem so formidable. He admits the certainty of such action, and, if the original proportion of these salts were not high, there is little difficulty in accounting for the small amount now present.

XXVIII.—Some Criticisms by a Firebrick Manufacturer.

By G. R. L. Chance.

As a manufacturer of what are commonly known as Stourbridge firebricks, it has been my ambition ever since I went into business to go in for more scientific methods of manufacture with the object of producing better quality bricks for various classes of work, and not necessarily the same brick for every class of work, as has often been the practice of not a few firebrick works in the past.

With this object in view we built a laboratory at our works about five years ago, and we now have installed there an embryo chemist who is, I think, all the President would say he ought to be, in that he has taken first prize at all the examinations he has entered for and attends technical classes regularly.

I must confess, however, to a feeling of great disappointment and discouragement due to the attitude still adopted very prevalently by users of firebricks in this country, and at times I almost feel tempted to devote myself to the most economical production of the same quality firebrick which we have been making for 60 or 70 years with some success, and leave scientific investigation to others.

I speak as a manufacturer of firebricks only, as distinct from any other kind of refractory material; I only speak from my own experience and I propose to be perfectly candid.

The first consideration of a business man is to make his business pay. The question then arises: "Is scientific research so far as it concerns the individual firebrick manufacturer going to pay him for the outlay expended?"

The success of any business depends on three things: (1) the efficiency of the sales department, (2) cheapness or economy in cost of production, and (3) the quality of the finished product. In my opinion, in a firebrick business, the first of these considerations is far and away the most important, and the last easily the least by comparison with the other two. I do not mean to imply that your business is likely to be successful if your goods are bad or inferior to most others on the market, but, given a reasonably good quality brick, I have

as yet found comparatively little incentive from users of firebricks to improve the quality still further.

Now this, I think, is all wrong, and does not make for progress, and I am looking to the Refractory Materials Section of the Ceramic Society to help us so to alter the situation that the success of a firebrick business shall be more commensurate with the quality of goods turned out.

One of the most interesting papers I have listened to was read before this Society at Stourbridge by Mr. Brooke, of the Shelton Iron & Steel Co.; the reason it particularly interested me being that it contained a long indictment of the silica brick manufacturers for making rotten bricks, and gave the makers an excellent opportunity for defending themselves. I only regret that Mr. Brooke did not go further and say something about firebrick manufacturers, and I hope this may be taken as a hint to him or some other large user of firebricks to give his experience of the efficiency of the firebricks he uses. There is nothing more helpful than criticism.

I must confess that since I joined the Ceramic Society I have heard so much about silica bricks that I sometimes wonder whether the majority of firebrick users, at any rate in steel works, have not got all they require already.

I should like to give one or two examples of what I call the lack of encouragement given to manufacturers to make an improved quality firebrick.

1. In nine cases out of ten, where ordinary squares are wanted, an enquiry is sent out for "best quality firebricks," or perhaps "best quality Stourbridge firebricks" (I am of course dealing with enquiries in my own district). No specification is given and no details are given as to what particular work the bricks are wanted for. Generally speaking, the order is given to the firm quoting the lowest price, or, if the engineer or furnace builder has been in the habit of buying from one particular firm, a preference would perhaps be given to that firm of a few shillings a thousand; bricks 2/6 per thousand more in price I have had described to me by a customer before the war as being at "a considerably higher price," and something wonderful was expected for this extra half-crown. I have also known a prospective customer say he did not mind paying sixpence a thousand more for a better quality brick. My point is that either a very ordinary quality firebrick is wanted where perhaps the bricks are not going to be used to destruction, where they are not expected to stand a high temperature and where they should stand for some years; in other words, where the quality of the brick is not really a primary consideration, or else the quality of the brick is really

a consideration, in which case it seems absurd to split hairs over price.

2. I think firebrick users are often very unreasonable in another way also. They frequently will not allow manufacturers a reasonable time to make the special firebricks they want. The result of hurrying large stuff is generally disastrous. Take, for example, blast furnace lining lumps 6 in. thick and say 30 in. long. Unless they are dried slowly and burned slowly they will come out with black cores, cracked or warped. It is, I think, an unchallenged fact that the longer large bricks are given to dry the better they are, and that it is much better to set them in the kilns white hard. And yet time after time orders are held up for no apparent reason, and the bricks are then wanted in the minimum of time. Orders are often placed with firms who offer the quickest delivery, and for this reason the tendency is for manufacturers to offer quicker delivery than they ought to do, compatible with the bricks being made properly. The result is that either the bricks are badly made or the stipulated time for delivery is exceeded. In either case the manufacturer gets blamed.

For some classes of work it is essential that the bricks should be very well burned and of good shape, and it is a puzzle to me why firebrick users still haggle over a few shillings per ton or per thousand instead of paying a slightly higher price and insisting on the best quality brick. It is quite easy to make good and bad bricks with the same materials, but there is not always a strong incentive to a manufacturer to make the best brick if he is beaten down to the lowest halfpenny.

Here again I think blast furnace linings illustrate my point. Before the war thousands of tons of linings were made for 20/- per ton or thereabouts. I defy any firebrick manufacturer to say that he could make a reasonable profit at that price, and yet blast furnace managers will tell you that it is of great importance for the joints in a lining to be tight, the bricks to be evenly burned all through and to be perfectly flat, a standard of perfection which was often not reached with goods sold at three times the price. Furnace managers may blame the manufacturers for quoting such low prices, but I disagree, and in similar circumstances I should look at a very cut price with suspicion. The mere fact that many linings have been made in the past at no profit only goes to show that proper attention cannot have been given by either side to the quality of the goods.

While on the subject of blast furnace linings I would like to know the real reason why some blast furnace managers prefer comparatively small bricks 4 in. thick and about 14 in.

long, and others insist on large bricks 6 in. thick, each brick weighing about 1½ cwts. The reasons I have heard advanced are on the one hand that the smaller bricks are better burned, and on the other hand that it is preferable to have as few joints as possible, and that the fewer the joints the less chance there is of a rock on the bricks when laid. As a matter of fact, if the bricks are made perfectly, the chief objections would be removed in either case, and the smaller bricks could be turned out twice as fast. A great deal could be done with a carborundum wheel to remove slight imperfections of shape and thereby to ensure tight joints. I do not think the grinding action would do any harm to the brick, and I know that this process is adopted in Germany to complete the manufacture of certain bricks.

3. One occasionally meets with users of firebricks who insist on using firebricks coming from other districts for certain classes of work. When questioned they generally say, "Oh, we have tried Stourbridge firebricks often but they never last: we find those we are now using last longer and we do not propose to make a change." It is quite immaterial to the user whether your own brick has been tried or not. By Stourbridge firebricks are meant all bricks made within a radius of say six miles of Stourbridge, whereas there are several different fireclays used in that area, and bricks of several different qualities are made.

I think it is a mistake for a firebrick user to take up that attitude; he should help the manufacturer to find out the reason for failure by giving him what information he can, and by offering to make tests of his bricks in actual use by building them in with other bricks and watching their behaviour. Who knows but that he may eventually be rewarded by finding a brick even better than the one he was using. It is only by practical co-operation of this kind that progress can be made.

Wherever possible, when I have met with a case of this kind, I have asked permission to take one of the satisfactory bricks away with me for test in our own laboratory. I have found users always most obliging in this way, but when it comes to getting working trials made I can never get anything very satisfactory, at any rate I have seldom had any statistical results given to me. Laboratory tests are useful up to a point, but there is nothing to compare with a test made on a brick by actual use under working conditions.

As regards the tests which I have had done in our own laboratory I have sometimes found that the bricks from two different districts have a very similar analysis and refractoriness, and the real reason why one brick should do better than the

other appeared to be that it was burned better and had a lower percentage of contraction. I knew one instance where, in the case of two steel works, one works uses bricks from a district I will call X for the doors of its furnaces (and incidentally pays a very high price for them), because the bricks from the neighbouring district wouldn't last. The other works did precisely the opposite for exactly similar reasons. The bricks in both cases had to stand the same conditions.

In other tests I have found the analysis of two competitive bricks to be entirely different. In one instance I was told by the manager of a steel works that he had found another brick which would last six times as long for a certain purpose as our own brick which he had been in the habit of using for several years previously. I tested this brick in every way I could. It was machine made, and owing to insufficient tempering or pugging of the clay there were longitudinal cracks and creases in the brick; it had a poor refractoriness (cone 28—29), it showed a contraction of 2·99 per cent., but it had an entirely different chemical analysis to our own brick. Added to this, the brick came from another district, and was cheaper owing to the clay from which it was made being worked in a quarry instead of a mine. If anyone had been asked to look at this brick and give an impartial opinion about it, he would probably have said it was a bad brick; and yet there is no doubt as to the success of the brick in use, and though bad in theory it is good in practice.

I do not think firebricks should ever be described as "first" or "second" quality at all. What is "first" quality for one class of work is "second" quality for another class, and *vice versa*.

There is still a great deal of prejudice amongst users. Take, for instance, machine-made firebricks. There are, of course, different kinds of machine made bricks; but some users refuse to look at a machine-made brick of any kind for any purpose. Even wire-cut firebricks are quite as good and better than hand-made for certain purposes, though I still believe that hand-made are preferable in some cases. Perhaps some firebrick manufacturers will question this statement, as I believe there are works where all squares are now made by machine; but it is very largely a question of the nature of the fireclay. Some clays do not lend themselves to making good machine-made pressed bricks, though they may be all right for making wire-cut bricks. I am quite certain, however, that a wire-cut firebrick is decidedly inferior to a hand-made brick for some classes of work.

Some furnace builders like to see no iron specks on the bricks at all, and even prefer to use lightly burned bricks; others like to see a brick with iron spots in preference to an equally hard-burned brick without. Personally, I believe a certain amount of iron is not detrimental to the bricks, but often actually improves it by making it stronger. I think the suggestion made by Mr. Brooke in his paper for properly organized co-operation between the maker and user of refractory materials is an excellent one, and I hope something will be done soon to get the scheme actually working.

It has been said to me by more than one person eminent in what I might call the Refractory Materials world, that Stourbridge is losing its reputation fast, and if we don't put our house in order we shall soon be left out in the cold altogether. I have thought a good deal about it and have come to the conclusion that, compared to the general practice in this country, only in one way is Stourbridge behindhand, and that is in the type of kiln universally used throughout the district with one or two notable exceptions. I may say, however, that Stourbridge is not the only district by any means which is out of date in this respect, and I think this is a question which ought to be taken up very seriously. Fuel economy is really a national question, and I am convinced that it should be quite possible to save more than half the fuel used in firebrick works throughout the country if the question were tackled properly. For this reason I believe this is the most important question before the trade to-day, and I hope the Refractory Materials Section of the Ceramic Society will take up the subject seriously and without delay. I should like to see a committee formed to investigate all the different types of kilns in existence and try to come to some conclusion as to the best type of kiln for burning firebricks. During the last twelve months I, or some representative of my firm, have visited seven entirely different types of modern kiln, and I should like to acknowledge the kindness and courtesy we have always received from the users of these different kilns, who have given us all the information they could, and have often given practical tests of burning our own bricks in their kilns. In spite of this I have never yet been able to get reliable figures as to fuel consumption from any of the firms we have visited, with one exception. The usual reply to this question is that it all depends on the class of goods in the kiln and the quantity of fuel used. That is a truism, but no firebrick manufacturer makes only one size of brick, and many are unable to rely on a standard quality of fuel; but it should be quite possible to arrive at an average fuel consumption per ton of goods burned over a reasonably

long period, an average which would enable one to compare the fuel consumption of different types of kiln.

I think, however, that it is a subject which can far better be investigated by a Society such as this than by an individual firm acting on its own. There has been only one paper on this subject read before this Society and, as far as I know, there is only one book dealing with the matter, "Kilns and Kiln Building," by Mr. Searle, which is more a standard text book giving brief details of different types of kiln, but no details as to the actual performance of the kilns in practice. I have read in the Transactions of the American Ceramic Society most complete records of tests on a particular type of kiln, but I have never seen any such records published of kilns in this country.

Another subject I should like to see tackled without delay is the standardization of patterns. This was referred to by the President in his after-dinner speech at Swansea, so I need not enlarge on the subject. I would, however, like to point out that in the case of sleeves, stoppers and nozzles, it is often a question whether it is worth while quoting at all, the cost of tools and dies being out of all proportion to the value of an order of any reasonable size.

In conclusion, I must apologise that this paper cannot be said in any way to add to our knowledge of the manufacture of firebricks, and is barren of any scientific and technical details. I am a seeker after that knowledge myself, and this paper is written with the object of directing the attention of members of this Society to the desirability of getting some of the suggestions already made to them carried into effect without further delay. I do not know what has been done with regard to Mr. Brooke's suggestion for testing refractory materials in actual use, or with regard to the President's suggestion for the standardization of patterns just referred to. Though I shudder to think what some of our customers may think of me if they ever read this paper, I am only inviting criticisms from them and asking them to give us more problems to work out, as, without their help, I must own that I cannot find enough work for our chemist to do.

DISCUSSION.

Mr. W. HAMILTON:—I have not previously spoken at any of the meetings of the Society as I have been rather afraid of the scientific men. I belong to the commercial side, but I am interested in many of the questions raised in the paper

just read. Mr. Chance blames the user for not giving encouragement to the manufacturer. The unfortunate thing is that the manufacturer will not make his bricks to a standard. Some makers produce first, second, fourth and even sixth quality bricks from the same clay, and Mr. Chance should make a note of that. The steel works are faced with many difficulties in connection with refractories, and the conditions are not all alike. One class of material is good for one purpose, but is not good for another, and it is only after many trials that the user can select the brands best suited to meet the conditions. Firebrick manufacturers appear to be unable or unwilling to produce the same constant quality. Often they have not the right clay to give the desired result; but I am afraid that, in many cases, when suitable materials are available, they are not developed properly. Mr. Chance refers to the encouragement firebrick manufacturers require in the way of price. I do not think the manufacturers have any reason to complain about the prices paid during the last four years: they have had every encouragement to produce the best. There are some problems within my own knowledge which are urgently requiring solution. One is a firebrick for lining basic ladles. At our works we have tried every available composition; we have had bricks made specially and burned for longer periods and at higher temperatures than usual, but at the best we cannot get more than about eight taps. This, I believe, is reckoned an exceptionally good run, but it falls very far short of the life of an acid ladle. The matter is important, as it is not the price of the bricks which runs up the cost so much as the labour incurred in re-lining the ladles. If any manufacturer can produce a brick which will keep a clean surface and refuse to be washed away by basic slag, I wish he would let us have some at once at his own price. Another problem is to find a brick which will give a reasonable life in the small cupolas producing hot metal for the Bessemer process. What manufacturer can give us a brick to withstand the action of the metal and slags in these cupolas? If one can do this I am quite sure that my company will pay any price for it. I do not suggest that you should charge the price of chromite or magnesite, but any reasonable extra charge over ordinary firebricks. The manufacturers have much to do to meet the requirements of the modern steel works and every one should make the best possible brick from his own particular clay; and it is of the greatest importance that all bricks should be carefully moulded and well burned. I find the discussions at these meetings very helpful to me as a buyer, and, with the assistance of the laboratory at the works, I am getting to know something of what is required in the way of refractories.

Lt.-Col. C. W. THOMAS:—In the first place, what Mr. Chance describes is quite on a level with my own experience. In the past it has been extremely difficult to get to know to what specific conditions the material supplied is expected to stand up. If you go into a works they can perhaps give you a general idea, but nothing at all definite, consequently the maker of refractories is pretty much in the dark. The only cure for that is as Mr. Chance has indicated, much more extended technical knowledge on the part of both works and office staff.

Many of the difficulties of the present day might have been got over long ago if this position had been realised, but the unfortunate part of it all is that we are now starting very late. I do not doubt that, in time to come, the situation will not be all what it is now. The research work on refractories which has been started in various directions is bound to have a great effect, not only on the refractory industry itself, but on those industries which make use of refractories.

I must confess to a certain amount of sympathy with Mr. Chance's remarks on silica. I also have felt that the fireclay refractories have been to some extent obscured by the attention that has been given to silica at the meetings of the Section.

Mr. Chance has referred to the question of kilns, and there he touched upon a factor of the very utmost importance. There is no doubt that the average kiln in which refractories are burnt in this country is a back number. Doubtless the perfect kiln has not yet been devised; whether it ever will be I do not know, but, from the point of view of the maker, the two questions of fuel and labour are to my mind the dominating factors in the situation to-day. To burn to even moderately high temperatures, such as cone 12, involves an enormously increased consumption of fuel, which is in itself a profit, or rather a loss, at present prices. Labour, again, is largely affected by the type of kiln which you use. From the increased attention which is being given to these questions, in the shape of "car and tunnel kilns," it is evident that their importance is realised. In these kilns the economy of fuel is not perhaps greater than in a good continuous kiln of the ordinary type, but under favourable conditions of planning there should be considerable economy of labour also. Unfortunately, in my own district, and also in others, there are some almost "preglacial" works, which constitute a formidable barrier to progress. It is not given to everyone to start on open ground with plans carefully thought out to provide for the most efficient handling of the material from the storage banks to the loading point, and with room for expansion for an indefinite period. Most of us have

to remember certain very good counsel as to the putting of new cloth into old garments, and I have long ago come to the conclusion that it would in the end be cheaper to build a new works than to remodel an old one.

Certainly if the new demands of users are to be met, it will involve the scrapping of much of our present plant, and, if labour conditions are to be met fairly also, it will involve the entire remodelling of most of the existing works.

Even then the user will have to face the paying of increased prices for higher qualities, which is an economic truth that buyers have so far—*pace* Mr. Hamilton—failed as a whole to realise.

Sir William J. Jones:—We might get Mr. Chance and Major Thomas to give a paper entitled "The Vicissitudes of Stourbridge Firebrick Makers." I think there is no paper which I have ever read and listened to which carries home more forcibly the value of a Society such as this where makers and users meet on common ground. We might get Mr. Hamilton and Mr. Johns to give a paper on the part of users, and Mr. Chance and Major Thomas on the part of makers. With regard to the terms that had been given to the refractory makers by the Ministry of Munitions I have never yet heard a refractory maker say that he was too well treated; I have heard a great many refractory makers talk of the high price of steel and the enormous profits of the steel makers. My experience of the Ministry does not coincide at all with the expressions of opinion that Mr. Chance has set forth in the paper, and I am bound in fairness to bear testimony to refractories having been ordered at a higher price because they had been found more suitable for the purpose for which they were intended. The instances that I have had are numberless. I rather think Mr. Chance presupposes that his brick is a superior brick to the one which was quoted at a little less price, and I can easily believe that Major Thomas would say that his brick was equal to the Chance brick. I am very glad to feel that Mr. Chance has come forward and expressed himself so freely and frankly in the matter, because I think that even to air the grievances of manufacturers can only be productive of good.

I think the question of kilns is one that requires most serious investigation, and that, surely, is a subject upon which scientific knowledge is required. I am glad to hear Major Thomas confess that some of the works in his district belong to the "preglacial period." There is a great deal of work to be done by the Stourbridge maker in his own area before he

should proceed to attack faults outside his area. The question of transport is such a difficult one that we cannot enter into it here.

I know that Dr. Mellor has had in his mind to institute as soon as ever possible a careful and methodical investigation into the question of kilns. I have advocated for a long time at these meetings that gas-firing was the right thing, and I think that if you have outside gas producers, and you are firing your kilns as I found them being fired on the Continent and nearly independent of the human element, it stands to reason that gas-firing must be more advantageous, and there is not the slightest doubt as regards economy in working.

Mr. G. R. L. CHANCE:—In reply to Mr. Hamilton's remarks, there are several processes in the manufacture of firebricks, and the manufacturer has to rely on the human element too much to be able to guarantee every brick which is turned out to be of the same standard quality. For this reason a certain amount of selection is necessary, and the manufacturer who supplies a constant quality deserves encouragement, whereas the probabilities are that he only gets his price compared to that of others who, as Mr. Hamilton suggests, make six different qualities from the same clay.

As the President says, it is open to argument as to whether the firebrick manufacturer could afford to improve his quality during the war, or whether the steel manufacturer could not have better afforded to pay more for an improved quality; but in any case the conditions during the war were abnormal and are not a fair criterion on which to base an argument of this kind.

As regards bricks for lining basic steel ladles, my firm have made a speciality of this particular brick for some years and we are at present engaged in research work on the subject. I suggest, with great respect, that the fact that we have waited two months for samples which were promised in a few days by Mr. Hamilton's firm, is perhaps an apt illustration of the lack of encouragement which Mr. Hamilton questions.

With Sir William Jones' remarks about kilns I am in entire agreement, but otherwise I think he speaks from the point of view of and is prejudiced in favour of the user of firebricks. It was not my intention to defend Stourbridge by pointing out that other districts were no better, but merely to show that there was no reason why Stourbridge should always be made the special subject for attack. Stourbridge, being probably the pioneer district, might be expected to give a lead to other districts in up-to-date methods of manufacture; but

the mere fact of its being the pioneer has in one way been its undoing, because, as Col. Thomas says, it is much harder to bring an old plant up-to-date than to start afresh and put up a new plant.

I knew that Sir William's experience at the Ministry of Munitions would be invaluable in throwing light on a discussion of this kind, but I am glad to say that every firebrick works has its staunch supporters, and it would be interesting to know whether Sir William could not find instances of one user demanding A's bricks because they were better than B's, and another B's bricks because they were better than A's.

As more than one manufacturer said to me after the meeting, it is a somewhat invidious position in which to place oneself to criticize publicly the man you want to sell your stuff to the next day, but so far I have not found that the paper offended anyone, and I neither regret nor retract anything I said in it. I sincerely trust that others will speak out in public what they have already said in private conversation.

XXIX.—Further Notes on Zinc Furnace Refractories.

By J. A. Audley, B.Sc.

In the previous paper (Trans., 18, 43, 1919) a general account was given of the refractories used in connection with the distillation of zinc, with details from published researches on certain aspects of the industry, and references to many books and articles bearing on the subject were supplied. As the paper aroused considerable interest among those connected with the zinc industry, it seemed desirable to extend the references, and with this aim I undertook to select what seemed the more interesting and important points (including analyses) from such recent and earlier articles as were not consulted in the preparation of the first paper, many of the articles being rarely accessible except in certain special libraries, and most of them not in English.

As before, I do not propose to deal specially with the furnace bricks, for the consideration of them is not essentially different from that of high grade refractories in general. It is in reality in their case mainly a matter of proper selection and suitable treatment of the materials, due regard being paid to the proportioning and grading of the grog. This reminds me that in a passing allusion to furnace bricks made from St. Louis clay (p. 54) there is no mention of the fact that the mixture used for making these bricks consisted of 40 clay to 60 grog,[27a] a much larger proportion of grog than is commonly employed in our country. Special treatment (washing, etc.) of the clay to increase its plasticity, or substitution (partially or wholly) of a more plastic clay than that ordinarily used, in order to permit the employment of a higher proportion of grog, deserves serious consideration in this connection, particularly as the best qualities of bricks are only needed at places where they come into direct contact with the flames.

The following are further analyses of St. Louis clay, all from the same mine, given by Mühlhæuser.[27]

	Al_2O_3	SiO_2	Fe_2O_3	CaO
Top of mine	34·95	49·00	2·45	0·80
	33·80	50·00	2·20	0·40
	34·64	49·60	1·96	1·20
Bottom	34·46	49·40	2·94	0·80
Average of above. Dried at 120° C....	34·46	49·50	2·39	0·80
,, ,, Calcined	39·26	56·39	2·72	0·91
Average of a year's production				
Dried at 120° C.	35·02	50·02	2·76	0·70
Calcined... ...	39·26	56·08	3·09	0·78

	MgO	K_2O	Na_2O	Loss on ignition
Top of mine	0·58	—	—	13·00
	0·36	—	—	12·80
	0·66	—	—	12·90
Bottom	0·87	—	—	12·75
Average of above. Dried at 120° C....	0·62	—	—	12·86
,, ,, Calcined	0·71	—	—	0·00
Average of a year's production				
Dried at 120° C.	0·46	0·06	0·17	12·51
Calcined... ...	0·51	0·07	0·19	0·00

It will be noticed that the variations in composition are comparatively slight. The impurities in the St. Louis clay—consisting of felspar, carbonate of lime, spherosiderite, limonite, gypsum, and pyrite, with a few quartz grains, and no more than traces of titanium—amount to only 1·57 per cent. of the clay ready for use, after drying at 120°.C. The clay itself, passed through a sieve with 5,000 meshes per sq. cm., had the following composition, and melted at cone 30—31:

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Loss on ignition
48·00	34·59	3·83	0·50	0·48	0·02	0·13	12·59

St. Louis clay thus comes near in composition to two German clays, from Girode and Hettenleidelheim.

	SiO_2	Al_2O_3	Fe_2O_3	Loss on ignition	Melting point
St. Louis clay	48·00	34·59	3·83	12·59	Cone 30-31
Girode clay	48·50	35·10	1·80	13·06	,, 34
Hettenleidelheim clay ...	49·23	34·57	2·05	12·15	,, 33

On making St. Louis clay into a thin slip, and washing it through a No. 100 brass sieve until the water runs through nearly clear, then allowing to settle and decanting the water, and finally drying on a water bath the mud remaining as well as the crumbly residue on the sieve, the products analysed as follows:—

	SiO_2	Al_2O_3	Fe_2O_3	CaO
St. Louis clay	50·02	35·02	2·76	0·70
Sieved clay	50·06	35·82	2·28	0·46
Residue	50·60	34·20	3·24	0·58

	MgO	K_2O	Na_2O	Loss on ignition
St. Louis clay	0·46	0·06	0·17	12·51
Sieved clay	0·60	0·05	0·04	12·49
Residue	0·40	0·09	0·16	12·47

The melting points proved to be the same for all three.

The fine clay was found to be highly plastic, whereas the residue was only slightly plastic, though the composition was nearly the same. This suggests at once that considerable increase in plasticity might be produced in other fireclays if

a suitable washing process could be devised. In trials on a small scale it was found that to obtain practically all the clay in washed condition wet grinding was necessary, as boiling or dry grinding gave no more than 50 to 66 per cent. of the clay in washed condition.[27]

Still another analysis of St. Louis clay, but after calcination gave the following figures:[27c]

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O
Calcined St. Louis clay	56·08	39·26	3·09	0·78	0·51	0·07	0·19

Some analyses of old Belgian and Silesian retorts were given on p. 47. The following analyses by Mühlhæuser[26] of a Rhenish muffle and two American retorts may be instructive for comparison:

	SiO_2	Al_2O_3	Fe_2O_3	ZnO	CaO	MgO	K_2O	Na_2O
Rhenish zinc muffle	68·84	20·38	2·52	6·42	0·60	0·12	—	—
Illinois zinc retort	44·68	32·52	3·60	19·10	0·10	0·00	0·11	0·20
Kansas zinc retort	52·06	28·34	2·40	16·88	0·06	0·42	—	—

It was stated that Schulze and Stelzner failed to establish the cause of the blue coloration of zinc spinel in zinc muffle or retort bodies, and categorically stated that it was not due to titanium, as they were unable to detect any titanium in the isolated blue spinel. They, however, alluded to Kersten's observation [Berzelius: *Jahresber. über d. Fortschr. d. phys. Wissenschaft*, **20**, 97, 1840] that when zinc vapour was passed over ignited titanic acid (that is, titanium dioxide) the latter became blue, and also that when a solution of titanic acid in hydrogen sodium phosphate was ignited in hydrogen it became lavender blue, and treatment with water left a blue lower oxide of titanium, which became white on heating in an open vessel. Brandhorst[21] definitely states that the blue coloration in zinc muffles or retorts is due to reduction of titanium dioxide, but gives no authority or special reason for his statement. Possibly he may have had the above-mentioned observation of Kersten in his mind, and assumed that the titanium compound must be present. The only difficulty in connection with this explanation is that Schulze and Stelzner failed to detect the presence of titanium in the German material, and Mühlhæuser[27] asserted that mere traces of titanium are present in St. Louis clay. In a recent paper Mühlhæuser[22] quotes Brandhorst's dictum, apparently with full acceptance, so that he may perhaps have found indications of large quantities of titanium later. Verneuil suggested that the tint of the sapphire is due to the same substance (see *Chem. Ztg.*, **34**, 133, 1,384, 1910).

The brief allusions to zinc slags may be supplemented by a few observations from a recent article by Mühlhæuser.[24]

Though not formed in great quantities, these slags constitute a troublesome by-product which often damages the body of the retort. With other metals the production of slag is deliberately aimed at, but in the case of zinc it is sought to avoid or limit the formation of slags, or at least to make them as harmless as possible so far as composition is concerned. In some operations carried out with a small trial furnace at the works of the Matthiessen and Hegeler Zinc Co. in La Salle, the roasted mixture of Joplin ore and Wisconsin ore used was composed of 86·96 ZnO, 0·36 CaO, 0·08 CuO, 0·37 PbO, 1·28 Fe_2O_3, 2·22 Al_2O_3, 0·80 CaO, 0·07 MgO, 7·00 SiO_2, 1·19 S, and must have consisted essentially of zinc oxide, silica, alumina, iron oxide and zinc ferrite, gypsum, zinc sulphide and iron sulphide. After reduction of the roasted blende (50 lb. ore to 30 lb. anthracite) in the trial furnace, the residue had the following average composition (for 19 operations):

	ZnO	CdO	CuO	PbO	Fe_2O_3	Al_2O_3
Soluble in acid, per cent. ...	5·18	traces	0·30	0·10	8·40	1·60
Insoluble in acid, per cent....	0·76	—	—	—	0·96	3·36
Total, per cent. ...	5·94	traces	0·30	0·10	9·36	4·96

	CaO	MgO	SiO_2	K_2O	Na_2O	S	Carbon
Soluble in acid, per cent....	0·24	0·08	—	—	—	—	—
Insoluble in acid, per cent.	0·02	0·02	19·36	—	—	—	—
Total, per cent. ...	0·26	0·10	19.36	0·23	0·30	2 88	58·82

The residue, consisting of the matrix of the ore, of partly consumed anthracite, and of the mineral ingredients of the latter, is probably composed of the following substances: the metals iron and copper, zinc oxide and alumina, iron silicate, $Al_2O_3.SiO_2$, $CaSiO_3$, Na_2SiO_3, and K_2SiO_3, sulphides of calcium, iron, and zinc, silica, and zinc spinel ($Al_2O_3.ZnO$). The components of the glowing ash bed are partly sintered, partly melted, and partly neither sintered nor melted. During the reduction process, and especially at the end of it, some of the silicates in the ashes become liquified and absorbed. With rise of temperature inside the muffle after removal of the zinc, fluid products will always be formed more freely because of the power which silicates possess of dissolving free silica as well as bases (protoxides and sesquioxides) and aluminates. A softened mass is thus formed adhering to the bottom of the muffle or retort, and this slag residue accumulates in time. In the case in question, it was carefully removed from the muffle after 135 days, and on analysis the slag was found to be composed as follows:

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
Soluble in acid, per cent....	0·52	5·21	7·63	1·94	0·19
Insoluble in acid, per cent.	66·42	8·45	3·49	2·40	1·11
Total, per cent.	66·94	13·66	11·12	4·34	1·30

	K_2O	Na_2O	CuO	PbO	ZnO
Soluble in acid, per cent....	—	—	0·06	traces	1·60
Insoluble in acid, per cent.	—	—	0·10	—	1·82
Total, per cent. ...	0·52	0·48	0·16	—	3·42

The oxygen in bases to oxygen in silica is as 1 : 3. It is thus a trisilicate slag consisting chiefly of silica, alumina, ferrous oxide, and lime, with also a little zinc oxide.

The slags from the regular operation—charges of 54·8 lb. ore and 25·4 lb. anthracite per muffle, in the large reduction furnace—were found to have quite a similar composition as follows:

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
Soluble in acid, per cent....	0·00	2·72	4·92	1·08	0·00
Insoluble in acid, per cent.	65·12	14·14	3·00	5·94	0·65
Total	65·12	16·86	7·92	7·02	0·65

	K_2O	Na_2O	CuO	PbO	ZnO	S
Soluble in acid, per cent....	—	—	0·06	—	1·32	—
Insoluble in acid, per cent.	—	—	0·04	—	1·32	—
Total, per cent. ...	0·29	0·42	0·10	—	2·64	0·98

The oxygen in bases to oxygen in silica is as 1 : 2·8, the slag being thus similar to that last referred to. Both slags were typical (as regards appearance, behaviour, etc.) of the regular operation slags at that period. The slag was mostly viscous at the temperature in the muffle, and formed an incrustation lining the inside of the vessel, more especially at the bottom. The skin of slag adhering to the bottom, or more or less merged in it, protects the underlying bottom from the corroding influence of other slag of different composition, checks diffusion, prevents or retards volatilization of metal, and so helps to increase the yield.

Examination of damaged vessels removed from the zinc furnaces showed that the accumulating slag had seldom seriously attacked the body of the distillation vessel, and only here and there was evidence noted of absorption of the slag by the wall in the lower half of the muffle. Similar action probably takes place, in the early period of use, with the porous bottom. Ferrous oxide, which is by far the most important of the fluxing materials in the ashes, forms with silica first fayalite, Fe_2SiO_4; this, on being absorbed by the muffle body, takes up from the

latter more silica to form $FeSiO_3$, the melting point of which is 1,500° C., as compared with 1,155° to 1,075° C. for fayalite. Alumina is also dissolved, and such other bases as may be at hand, the product becoming more and more viscous until it finally solidifies. The material so formed is different in its properties from the original porous body, and is more liable to become cracked. It is also possible that ferrous sulphide (melting point 1,194° C.) present in the charge may penetrate the muffle body in places, to be converted later into Fe_2O_3 and then into FeO or $FeSiO_3$.

Good slags are nearly or quite neutral towards the muffle, and can remain in contact with it for a long time without injuring it.

The formation of a glaze or glassy coating on the outside of muffles—from the action of dust and fumes—does not prevent the entrance of furnace gases, or the exit of reducing gases or zinc vapour, but it materialy retards such movements, and therefore diminishes the formation of zinc dust while helping to increase the yield.[25] The rate of action depends on the extent of the slagged surface of the muffle, on the thickness of the glassy layer, and on the degree of viscosity of the latter.

The rate of formation of the glaze depends much on the position of the muffle in the furnace and on the nature of the dust, and may be assisted by the white fumes of burning zinc. In the front of the furnace (where the producer gas enters) the muffles are more quickly covered than further behind. Dust is mostly deposited continuously on the rough surfaces of new muffles, and of those already covered with a viscous layer. Increase of the glaze is to some extent regulated by a trickling down when it softens by overheating, and the excess may thus drip in succession from one vessel to another below it, and finally fall on the sand-covered bottom of the furnace.

The glaze after cooling is mostly black owing to the soot present, but sometimes it has a greenish or brownish tinge according to the character of the furnace atmosphere at the time the muffle was removed. But wholly brown muffles were seldom seen at La Salle.[25]

The following analyses show the composition of a dust such as formed a glaze on the body of a muffle, (1) before and (2) after its entrance into the zinc furnace, (3) the composition of the muffle body, and (4) the composition of the glaze itself (with 8·85 per cent. FeO instead of Fe_2O_3):

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	ZnO	PbO	C and S
1.	11·99	3·01	5·16	0·46	0·06	0·34	0·44	—	—	rest
2.	13·10	4·66	7·44	0·24	0·02	0·48	0·52	30·04	0·78	rest
3.	44·68	32·52	3·60	0·10	0·00	0·11	0·20	19·10	—	1·29S
4.	50·26	31·84	8·85 (FeO)	1·40	0·36	1·09	1·68	3·20	0·28	1·04C

The oxygen ratio of acid to base was 2:1, so that it was a bisilicate. The formula was: 0·519 FeO, 0·106 CaO, 0·039 MgO, 0·049 K_2O, 0·114 Na_2O, 0·006 PbO, 0·167 ZnO, 3·544 SiO_2, 1·321 Al_2O_3, 0·366 C.

Another glaze gave on analysis: 54·98 SiO_2, 32·78 Al_2O_3, 5·47 FeO, 1·96 CaO, 0·64 MgO, 0·51 K_2O, 1·81 Na_2O, 0·04 PbO, 0·22 ZnO, 1·59 C., corresponding to the formula: 0·461 FeO, 0·213 CaO, 0·098 MgO, 0·034 K_2O, 0·177 Na_2O, 0·001 PbO, 0·016 ZnO, 5·570 SiO_2, 5·570 SiO_2, 1·954 Al_2O_3, 0·805 C. The oxygen ratio between acid and base was 1·602:1, indicating a sesquisilicate.

The analysis of a glaze which had formed gradually about the centre of the middle wall of a large zinc furnace may be of interest:

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	ZnO
St. Louis clay (calcined)	56·08	39·26	3·09	0·78	0·51	0·07	0·19	—
Grog (7 years in the fire)	55·96	39·49	2·02	0·97	0·39	0·06	0·05	1·07
Glaze (on brick)... ...	54·31	36·50	2·22	0·79	0·35	2·92	1·76	0·99

The 2·22 per cent. of Fe_2O_3 in the glaze represents 2·00 per cent. of FeO. The oxgyen ratio between base and acid was 1:1·516, indicating a sesquisilicate. The formula of the glaze was: 0·183 FeO, 0·122 CaO, 0·078 MgO, 0·269 K_2O, 0·244 Na_2O, 0·104 ZnO, 7·869 SiO_2, 3·078 Al_2O_3. This glaze was fusible with difficulty, and did not penetrate further into the body, but just like the muffle glazes it was liable to become mobile and flow away when the temperature of the furnace was accidentally raised.

In choosing the heating arrangements for a zinc furnace, due regard should be paid to the advantageous influence on the yield of zinc, of the glaze coating on the outside of the distillation vessels. When firing with coal is adopted, and a coal rich in iron is available, a suitable producer should be placed in convenient proximity to the zinc furnace, so that the vessels may be exposed to sufficient dusting with the ash. From this point of view, natural gas and Mond gas—in spite of advantages due to homogeneous composition of the gas and the possibility of uniform heating—are by no means ideal combustibles, because they carry no dust with them. When such gases are employed for firing zinc furnaces it is desirable to remedy the deficiency by special glazing of the muffles, which, though not an easy problem, should not be impossible of solution.[25]

The colour of the glaze of a zinc muffle is, in the back part of a zinc furnace (where the gases have already become mixed uniformly), black, grey, green, or brown. In other places different parts of the surface may have the different colours, as grey, green, brown.

The glaze covering the blue body is green, like every muffle influenced by a reducing flame. When much soot is present in the flame the glaze is black; when zinc vapour, escaping through a crack or hole in a neighbouring muffle, burns to zinc oxide, a green or milk-white glaze is formed; when the green surface of the muffle was exposed to a transient oxidizing flame the glaze became brownish, or wholly brown with longer action of such a flame. Very rarely the glaze is nearly colourless and transparent, and appears blue because of the blue body which it covers.[22]

The tempering (preheating or annealing) of zinc muffles before introducing them into the zinc furnace needs careful attention. The body is least sensitive to sudden cooling or heating when the constitutional water of the clay has been expelled, but without melting any of the fluxing material present in the body of the muffle. This is because the components of the body are still in practically the same unconstrained state as they were in just after the drying contraction, and the binding material (of the St. Louis clay in this case) has not yet begun to shrink. With overheating, sintering would set in, and the whole or parts of the vessel would begin to shrink, and the resulting strains would be liable to cause cracking and dislocation when temperature changes occurred. It is therefore important to avoid both total and local overheating as far as possible, in order to escape serious risks.[23]

The tempering furnace is set while still very hot (over 100° C.), and after being closed up the contained muffles (or retorts) are left to themselves about 15 hours. Then a small fire is kindled, and the heat is increased very gradually so that in 24 hours or so the temperature reaches about 800° C., at which it should then be maintained until the muffles are taken out. The actual time of tempering is about 24 hours, the muffles being altogether about 40 hours in the furnace.

The gases about the muffles also diffuse into the bodies of the muffles, and reduction or oxidation actions take place according as combustible gases (CO, H, ammonia, hydrocarbons) or oxygen are in excess. Sulphur, H_2S, and SO_2 may in some circumstances exercise a sulphating action. Ferrous oxide in the muffle body takes up oxygen to form higher oxidation products, and these are in turn converted by the reducing gases into ferrous oxide or may even be reduced to metallic iron temporarily. The prevailing atmosphere during tempering is reducing, but oxidizing conditions sometimes arise.

The loss of constitutional water from clay takes place mostly between 375° and 666° C., and finishes at about 800°.[23]

Pyrite loses gradually more and more sulphur as the temperature rises, from 200° C. onwards, the maximum being reached at 700° C.; ferrous sulphide (FeS) or magnetic pyrites (Fe_7S_8) is formed, or mixtures of FeS with FeS_2 and Fe. The decomposition products remain solid, since their melting point is never reached in the tempering furnace; the decomposition will take place there at a somewhat higher temperature, the bulk of the pyrite crystals being in the muffle body. Besides FeS and Fe, the decomposition products of pyrite may contain FeO and Fe_2O_3. Above 290° and up to 500° C., oxidation of pyrites slowly produces Fe_2O_3 and SO_2 only. Beyond 500° C. the oxidation of the FeS_2 may be preceded by a cracking. Sulphur is first distilled off as such, and combines with oxygen to form SO_2. Then the FeS is completely burned or roasted. But this will not be normal in the tempering furnace.

The decomposition of substances like spathic iron, limonite, gypsum, etc., takes place at comparatively low temperatures. Quartz in the muffle body is subject to sudden increase of volume at 570° C., and the strains produced give rise to cracks, and can sometimes cause complete destruction. But generally the amount of quartz is small, and its effects are scarcely noticeable. As a result of the reaction very small spaces are produced between the grains.

The tempered muffle is a moderately hard stone body, consisting of alumina and silica with small quantities of other substances which later partly act as fluxing materials, and then increase the strength of the body. It is remarkably porous, and the for the most part very small cracks, fissures, cavities, etc., form a connecting system of spaces spreading through the muffle body from inside to outside. This system of spaces is highly permeable, either hot or cold, for gases, and towards thinly fluid fluxes the body behaves like a capillary tube system.

The body is homogeneous, fairly dense, and reasonably strong, and endures the temperature prevailing in the zinc furnace (maximum 1,300° C.) and occasionally pointed flames (1,600° C.), as well as abrupt temperature changes, and it is also a fairly good conductor for heat.

The gradual vitrification of parts of the muffle walls (especially bottoms) decreased refractoriness and resistance to sudden changes of temperature, but increased the strength, elasticity, and extensibility, so that the average life of the muffle was 63 days.[23]

In the brief reference (in the previous paper) to the possible advantage from coating the distillation vessels with zirconia, it should have been pointed out that the very small contraction of zirconia causes practical difficulties in connection with such

applications. These would in all probability be overcome if it were practicable to apply a number of coatings in succession, each with a larger proportion of zirconia than its immediate predecessor, and finishing with zirconia alone. The best grades of natural zirconia should be good enough for such purpose, without any chemical treatment.

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[27] Mühlhæuser, O. St. Louis Clay. *Zeits angew. Chem.*, 148, 1903. Also other papers by same author in that volume at pp. 222 ([27a]), 391 ([27b]), 737 ([27c]) 761 ([27d]), 1,055 ([27e]), 1.107 ([27f]), and 1.124 ([27g]), which though not immediately concerned with zinc furnace refractories, relate to investigations of St. Louis clay and of products prepared from mixtures of the clay and variously graded grog made from the same clay. The article on p. 391 ([27b]) relates to ceramic methods of measurement, etc.

[28] Smith, E. A. The Zinc Industry, 1918.

[29] Babcock, M. G. Refractories for the Zinc Industry. *J. Amer. Cer. Soc.*, **2**, p. 81, 1919 (Feb.).

XXX.—A Note on Blue Glass.

Communications from the Clay and Pottery Laboratory, Stoke-on-Trent.—No. 89.

By J. W. Mellor, D.Sc.

In the early days of the Zeppelin raids there was a demand from several sources for a blue glass for lamp bulbs. Nothing seemed simpler than to add a few per cent. of cobalt oxide as colouring agent, but, when this was done, it was found that the incandescent filament viewed through this glass appeared to be red, and to a person more or less short-sighted the incandescent lamp appeared to glow with a red light surrounded by a blue halo. It was therefore decided to cut out the red rays.

Since blue powder is used in the laundry for masking the complementary yellow or cream colour of the linen, and blue cobalt oxide is likewise used by the potter for masking the cream colour due to iron oxide in his white bodies, it obviously follows that the introduction of a green colouring oxide might reasonably be expected to cut out or mask the complementary red. Copper oxide was first tried but it was not so good. A small proportion of chromic oxide with the cobalt oxide proved perfectly satisfactory, and gave a glass which succeeded admirably in cutting out the red rays and transmitting nothing but the blue.

I was rather curious about the absorption spectra of these glasses, and Mr. C. Edwards kindly made up a few glasses with the proportions of the two oxides indicated in Table I. There is no need to give the recipe for the glass, which may be regarded as a standard lead-lime-soda glass.

The proportion of the mixture of colouring oxides is indicated in the last column of the table. The glasses were annealed and then ground to thin plates 0·5 mm. in thickness. The absorption spectrum of each glass was photographed by means of a Hilger quartz spectrophotometer. The spark spectrum of nickel was used as a standard. In order to compensate for the general absorption of the glass the sectors of the instrument were so adjusted that the opening of the

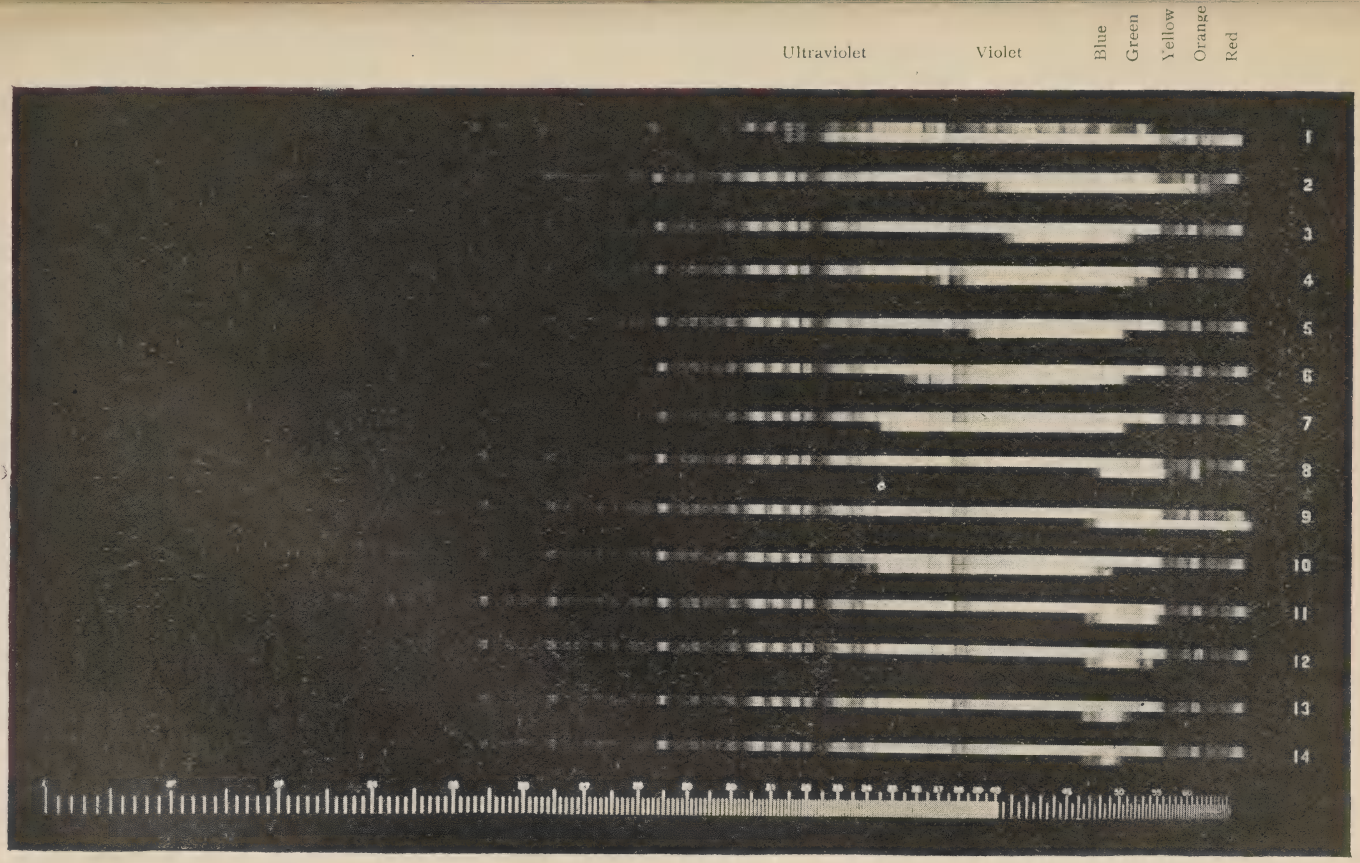
Ultraviolet
Violet
Blue
Green
Yellow
Orange
Red
1
2
3
4
5
6
7
8
9
10
11
12
13
14

Fig. 1.

"standard" sector was one-twentieth that of the "test" sector. The exposure in each case was thirty seconds and Ilford panchromatic plates were used.

Table I. Colour Stains.

No.		Cobalt Oxido	Chromium Oxide	Copper Oxide	Per cent. used as stain
1	Unstained glass - -	0	0	0	0
	Copper-cobalt series -				
2	,,	0	0	20	4
3	,,	5	0	20	5
4	,,	10	0	20	3
5	,,	20	0	20	4
6	,,	40	0	20	3
7	,,	80	0	20	2·5
8	,,	100	0	0	2
	Chromium-cobalt series				
9	,,	0	20	0	0·4
10	,,	10	20	0	0·6
11	,,	25	20	0	0·9
12	,,	60	20	0	1 2
13	,,	150	20	0	1·7
14	,,	200	20	0	2·2

No. 1 shows the absorption spectrum of the glass alone. No. 2 the same glass stained with copper oxide, No. 8 with cobalt oxide. Note how mixtures of the two cut out the green to red portion of the spectrum.

Again, No. 8 is cobalt oxide, and No. 9 chromic oxide alone, and mixtures of the two cut out the violet and yellow to red portion, until finally, with No. 14, little more than the blue rays are transmitted. There is some doubt about No. 10. It looks as if a mistake had been made somewhere, but it does not effect the principle brought out in the diagram.

In passing it was noticed that with the higher proportions of chromic oxide—Nos. 11–14—a tint approaching ruby red was sometimes developed.

The different glasses were annealed by Messrs. Chance of Birmingham, cut into plates by Messrs. Hilger, and the absorption spectra were kindly photographed by Dr. A. Scott. The results are indicated in Fig. 1.

XXXI.—Factors Influencing the Properties of Silica Bricks (Part I).

Communications from the Clay and Pottery Laboratory, Stoke-on-Trent.—No. 90.

By Alexander Scott, M.A., D.Sc.

THE chief non-siliceous materials which occur in the rocks used in the manufacture of silica bricks are alumina, titanic oxide, iron oxide, lime, magnesia and alkalies, the amount of any one of them being generally less than 2 per cent. The object of this work is to investigate the effects of some of these on the inversion of the quartz to the high temperature forms and on the properties of silica bricks generally. In the present paper, the properties considered, in addition to the conversion, are apparent and true specific gravities, porosity, after-expansion and refractoriness; it is hoped that certain others, such as refractoriness under load, will be considered later. In many cases the exact form in which these impurities occur is not determinable; they are probably present in the thin layers of amorphous material which cement together the crystals of quartz. Occasionally they are found in the form of identifiable minerals such as felspar, mica, calcite, pyrites, etc. In order to gain some idea of the influence of each impurity, or combination of impurities, it is necessary to use as pure a quartz rock as possible, and for this reason vein-quartz was adopted, although it is usually unsuited for the manufacture of silica bricks. The method of investigation consisted in bonding as pure a silica rock as possible with a small percentage of other material, firing to various temperatures and examining the bricks so made.

The silica rock used was vein quartz of a fairly high degree of purity. A microsection showed it to consist of large interlocking crystals of quartz, showing strain shadows (wavy extinction) between crossed nicols and containing some very minute mineral and gas inclusions. The crystals were too small for very definite identification, but some which had a high refractive index and were isotropic were possibly garnets. The quartz grains formed a mosaic with no visible cementing material between the crystals. So far as microexamination showed, the total amount of impurity was less than one half

per cent. The rock was broken up in a small steel crusher and sieved. Some of the material was treated with acid in order to see if much iron had been added in the crushing, but the amount extracted was negligible.

The crushed material was sampled and analysed, the results being given in Table 1. It is possible that part of the iron oxide found was introduced during the crushing, but most of it was probably present in the minute crystalline impurities in the original rock. As the total alkalies did not exceed 0·08 per cent. the sodium and potassium oxides were not determined separately.

TABLE 1.—ANALYSIS OF THE QUARTZ USED.

SiO_2	99·46
TiO_2	nt. fd.
Al_2O_3	0·20
Fe_2O_3	0·24
MgO	trace
CaO	0·13
K_2O / Na_2O	0·08
Loss on ignition ...	0·10
	100·21

For the making of the bricks, the material which failed to pass a 4's sieve was rejected, and the remaining fractions taken in such proportions as to give practically a "straight line grade." Table 2 shows the percentage of each grade used.

TABLE 2.—GRADING OF THE GROUND MATERIAL.

Through 4's on 8's sieve ...	5·5
,, 8's on 16's ,, ...	7·5
,, 16's on 40's ,, ...	9·5
,, 40's on 60's ,, ...	11·5
,, 60's on 80's ,, ...	13·5
,, 80's on 100's ,, ...	15·5
,, 100's on 120's ,, ...	17·5
,, 120's	19·5
	100·0

The bonding materials used were as follows:—A, Lime (CaO). B, Magnesia (MgO). C, Alumina (Al_2O_3). D, Iron oxide (Fe_2O_3). E, Iron oxide (Fe_2O_3) + carbon. F, Titanic oxide (TiO_2). G, Lime and magnesia. H, Lime and alumina. I, Lime and iron oxide (Fe_2O_3). J, Lime, iron oxide and carbon. K, Lime and titanic oxide. L, Magnesia and alumina. M, Magnesia and iron oxide. N, Magnesia, iron oxide and carbon. O, Alumina and iron oxide. P, Alumina, iron oxide and carbon. Q, Lime, iron oxide and titanic oxide. R, Glen-

boig fireclay. S, China clay. The materials were ordinary laboratory chemicals except in the case of the last two. The amount used was 2·5 per cent. in the case of the simple oxides, 1·25 per cent. of each where two oxides were used, and in Q 1 per cent. of each. The carbon was ordinary charcoal and the amounts in E were 2·5 per cent. oxide and ·5 per cent. charcoal, and in J, N, P, 1·25 per cent. of each oxide and ·25 per cent. charcoal.

The bricks were made in a vertical tile press, the approximate size being 2 in. × 2 in. × 1 in. After drying they were hardened sufficiently for transport by firing in a pottery kiln to cone 8, the duration of firing being 24 hours. The blocks were then fired for the usual period in a silica brick kiln to three different temperatures, cone 14, cone 16, and cone 19.

Microexamination.—The blocks fired to cone 19 were sectioned and examined under the microscope.

A (CaO). The fine material has undergone considerable conversion, but the larger fragments are only slightly altered on the margins and along cracks which have developed during the firing. Small crystals of calcium silicate, with high double refraction are visible in the matrix.

B (MgO). The larger grains have undergone more alteration and are more shattered than in B. The matrix is apparently glassy.

C (Al_2O_3). The margins of the fragments are very clearly defined, but a certain amount of alteration has occurred throughout these. A few crystals of sillimanite are visible in the matrix.

D (Fe_2O_3) and E (Fe_2O_3+C). These two are very similar. The marginal attack is fairly pronounced. The matrix contains numerous crystals of magnetite, and in E some hæmatite which may have formed by the oxidation of fayalite (ferrous orthosilicate), as small somewhat decomposed crystals of the latter are visible.

F (TiO_2). The outlines of the quartz fragments are sharp. Minute crystals, with very high refractive index and double refraction in the matrix suggest rutile.

G (CaO+MgO). The fragments have been attacked at the margins. The matrix contains crystals, probably of a pyroxenic nature, with high double refraction.

H (CaO+Al_2O_3). The fragments are considerably altered and closely resemble those in commercial silica bricks. The matrix is partly glassy.

I (CaO+Fe_2O_3). The alteration of the quartz is very considerable round the grain margins, and there is a glassy matrix containing microlitic crystals which are apparently pyroxene.

J (CaO+Fe_2O_3+C). Similar to I. In the matrix brown crystals resembling decomposed pyroxene occur.

K (CaO+TiO_2). Quartz is much altered. The matrix is crystalline with several types of crystals, some of which are apparently calcium metasilicate.

L (MgO+Al_2O_3). Resembles H. Some crystals in matrix.

M (MgO+Fe_2O_3) and N (MgO+Fe_2O_3+C) These are very similar. Only the fine-grained quartz is altered. Magnetite and altered fayalite (?) occur in the base.

O ($Al_2O_3+Fe_2O_3$) and P ($Al_2O_3+Fe_2O_3+C$). In both cases the quartz has undergone considerable alteration both marginally and throughout the grains. The latter are much cracked. The matrix contains crystals of hæmatite.

Q ($CaO+Fe_2O_3+TiO_2$). Quartz is much altered. Matrix is crystalline and contains cristobalite, fayalite, hæmatite, and some unidentified crystals.

R (Fireclay). The larger quartz grains have not undergone much conversion, but the smaller are completely altered. Magnetite and sillimanite occur in the base.

S (China clay). The "conversion" has penetrated the quartz grains considerably. The matrix is not visibly crystalline.

Conversion of the Quartz.—The factors which influence the conversion of the quartz include the nature and amount of the non-siliceous materials present, the grain size of the quartz, the temperature of firing and the duration of firing. In order to test the effect of these, the amount of residual quartz, left unconverted after 72 hours' firing, was measured microscopically in the case of blocks A and J, the firing temperatures being cones 14, 16 and 19. The results are given in Table 3.

TABLE 3.—PERCENTAGE OF UNCONVERTED QUARTZ IN BLOCKS FIRED TO DIFFERENT TEMPERATURES.

	Bond	Cone 14	Cone 16	Cone 19
A	CaO	65·4	63·6	61·4
J	$CaO+Fe_2O_3+C$	59·1	57·0	52·1

The results show that the conversion can be considerably increased if the firing temperature be increased. Since the rock used in this case was vein-quartz, the conversion of which will in general proceed much more slowly than in the case of a ganister, the increase in conversion of the quartz in the latter is likely to be appreciably greater.

Although the question of the influence of the grain size of the quartz was not directly investigated in this instance, it is very probable that the degree of conversion varies with the fineness of grain. As the quartz seems to be converted mainly through the agency of the bonding material which dissolves the former and reprecipitates it as cristobalite, this conversion will be greatest when the surface of quartz exposed to the solvent is a maximum, that is, when the grain-size is a minimum. In actual practice, however, the diminution in grain-size is limited by other considerations relating to crushing strength and so forth.

The influence of the duration of firing has likewise not been directly tested, but such evidence as is available indicates that the conversion can be increased by "soaking" at high

temperatures. Seaver,[1] Ross,[2] and Insley and Klein[3] have investigated the effect on the conversion of successive heatings to various temperatures, but only the first named gives quantitative details. From some trials carried on by the writer, on bricks made from ganister, the effect of successive heatings to cone 14 resulted in a steady increase in the proportion of the high temperature forms, but this increase was not sufficiently great to make such repeated firings an economic practice. On the other hand, it is possible, by heating to cone 20 and maintaining at that temperature for a considerable period, to reduce the residual quartz to negligible proportions.

The results in Table 4 indicate the effect of the nature of the non-siliceous material present. The measurements were all carried out on bricks fired to cone 19.

TABLE 4.—SHOWING THE PERCENTAGE OF UNCONVERTED QUARTZ IN BRICKS FIRED TO CONE 19.

Brick	A	B	C	D	E	F	G	H	I
Percentage of residual quartz	61·4	65·4	76·5	57·1	58·8	68·5	71·2	60·0	51·3

Brick	J	K	L	M	N	O	Q	R	S
Percentage of residual quartz	52·1	62·7	65·7	63·3	62·0	52·5	49·0	58·3	62·0

Of the blocks to which only a simple oxide has been added, the greatest degree of conversion is found in those which contain iron oxide. Lime seems to have almost as great an influence, while the amount of residual quartz steadily increases with magnesia, titanic oxide and alumina, the last giving a considerably smaller amount of the high temperature forms than the others. In general the effect of the presence of a second oxide is to increase the conversion; thus iron oxide, added to lime or magnesia, diminishes the proportion of quartz, while alumina has a similar but smaller effect. A mixture of lime and magnesia gives a relatively low degree of conversion, but with alumina and iron oxide, on the other hand, it is high. The low proportion of quartz, in the case of Q, is probably partly due to the fact that the added material amounts to 3 per cent. The addition of carbon to those blocks containing iron oxide does not seem to have had any appreciable effect; this may, however, be due to the carbon being largely burned out in the initial firing. In general the conversion is greatest in those cases in which bonding material forms a relatively fusible mixture with the fine-grained silica of the matrix.

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1 *Trans. Amer. Inst. Min. Eng.*, **53**. 137, 1916.

2 *U.S. Bureau of Standards, Tech. Paper*, **116**, 57, 1919.

3 *Ibid.*, **124**, 13-31, 1919.

Specific gravity.—The determinations of the true and apparent specific gravities were carried out by the methods described in the Standard Specification of the Institution of Gas Engineers.[1] The true specific gravity tends in most cases to vary directly as the firing temperature, while the apparent specific gravity follows similar lines. The results for the former are given in Table 5, and for the latter in Table 6. Where the bonds are simple oxides, as in A, B, C and D, the apparent specific gravity is considerably lower after firing to cone 14 than to cone 8, but the difference between the former and the values for cones 16 and 19 is slight. Where the bonds contain two oxides, as in J, K, N and O, the diminution is fairly steady for the higher temperatures. The true specific gravity may be taken as giving a qualitative idea of the amount of conversion, but the quantitative relation is only approximate.

TABLE 5.—SHOWING THE VARIATION OF TRUE SPECIFIC GRAVITY WITH TEMPERATURE OF FIRING AND NATURE OF BOND.

	Bond.	Cone 8.	Cone 14.	Cone 16.	Cone 19.
A	CaO	2·61	2·50	2·49	2·51
B	MgO	2·63	2·60	2·55	2·56
C	Al_2O_3	2·64	2·62	—	2·61
D	Fe_2O_3	2·62	2·53	2·53	2·51
E	Fe_2O_3+C	2·61	2·52	2·50	2·49
F	TiO_2	2·60	—	2·58	2·57
G	$CaO+MgO$	2·61	2·58	2·55	2·57
H	$CaO+Al_2O_3$	2·57	2·56	2·53	2·52
I	$CaO+Fe_2O_3$	2·53	2·48	2·48	2·45
J	$CaO+Fe_2O_3+C$	2·55	2·48	2·49	2·46
K	$CaO+TiO_2$	2·55	2·53	2·51	—
L	$MgO+Al_2O_3$	2·62	2·58	2·56	2·55
M	$MgO+Fe_2O_3$	2·60	2·54	2·56	2·54
N	$MgO+Fe_2O_3+C$	2·60	2·56	—	2·55
O	$Fe_2O_3+Al_2O_3$	2·55	2·52	2·50	2·46
P	$Al_2O_3+Fe_2O_3+C$	2·55	2·52	2·50	2·47
Q	$CaO+Fe_2O_3+TiO_2$	2·51	2·49	2·47	2·44
R	Fireclay	2·59	2·53	—	2·49
S	China clay	2·60	—	2·55	2·53

Although, in the present instance, special precautions were taken to ensure, in the specific gravity determinations, an absorption of water as complete as possible, the discrepancies between the determined true specific gravity and that calculated from the results in Table 4, are considerable. Since, in every case the high temperature form present was practically all cristobalite, 2·33 may be taken as the specific gravity of a completely converted block. The total amount of glassy (bonding) material present will be less than 5 per cent., and

[1] TRANS. 17, 314, 1918.

hence the error involved in ignoring it will not exceed 0·01, so far as the true specific gravity is concerned. Nevertheless, the specific gravities, calculated from the results of Table 4, may differ from the determined values to the extent of 0·04. Conversely, if with the same assumptions the degree of conversion be calculated from the determined specific gravity, the results may differ from those in Table 4 to the extent of ± 12 per cent. Hence, the specific gravity, determined by this method, gives only a very approximate idea of the degree of conversion of the quartz.

TABLE 6.—SHOWING THE VARIATION OF THE APPARENT SPECIFIC GRAVITY WITH TEMPERATURE OF FIRING AND NATURE OF BOND.

	Bond.	Cone 8.	Cone 14.	Cone 16.	Cone 19.
A	CaO	1·78	1·75	1·74	1·75
B	MgO	1·82	1·78	1·78	1·77
C	Al_2O_3	1·77	1·72	—	1·72
D	Fe_2O_3	1·80	1·77	1·76	1·76
E	Fe_2O_3+C	1·72	1·72	1·69	1·67
F	TiO_2	1·78	—	1·74	1·73
G	CaO+MgO	1·74	1·69	1·68	1·70
H	CaO+Al_2O_3	1·81	1·79	1·80	1·80
I	CaO+Fe_2O_3	2·75	1·75	1·74	1·74
J	CaO+Fe_2O_3+C ...	1·82	1·79	1·77	1·75
K	CaO+TiO_2	1·80	1·79	1·76	—
L	MgO+Al_2O_3	1·75	1·72	1·71	1·71
M	MgO+Fe_2O_3	1·80	1·78	1·78	1·72
N	MgO+Fe_2O_3+C ...	1·77	1·75	—	1·74
O	Fe_2O_3+Al_2O_3	1·71	1·70	1·69	1·67
P	Al_2O_3+Fe_2O_3+C ...	1·71	1·68	1·67	1·67
Q	CaO+Fe_2O_3+TiO_2 ...	1·78	1·75	1·76	1·76
R	Fireclay	1·78	1·74	—	1·70
S	China clay	1·80	—	1·76	1·75

TABLE 7.—SHOWING THE VARIATION OF POROSITY WITH TEMPERATURE OF FIRING AND NATURE OF BOND.

	Bond.	Cone 8.	Cone 14.	Cone 16.	Cone 19.
A	CaO	31·8	30·0	29·3	30·2
B	MgO	30·8	31·4	30·2	30·8
C	Al_2O_3	33·1	33·8	—	34·0
D	Fe_2O_3	31·2	30·0	30·4	29·8
E	Fe_2O_3+C	34·0	32·0	32·2	32·9
F	TiO_2	31·6	—	32·5	32·7
G	CaO+MgO	33·3	34·5	34·2	33·7
H	CaO+Al_2O_3	31·8	31·6	31·2	31·0
I	CaO+Fe_2O_3	28·4	28·0	27·4	26·5
J	CaO+Fe_2O_3+C ...	28·3	27·9	29·0	28·8
K	CaO+TiO_2	29·2	29·5	29·9	—
L	MgO+Al_2O_3	33·2	33·4	33·2	33·4
M	MgO+Fe_2O_3	30·8	29·9	30·4	32·4
N	MgO+Fe_2O_3+C ...	31·5	31·8	—	31·9
O	Fe_2O_3+Al_2O_3	33·0	32·5	32·4	32·2
P	Al_2O_3+Fe_2O_3+C ...	32·6	33·5	33·4	32·4
Q	CaO+Fe_2O_3+TiO_2 ...	29·2	31·5	28·7	27·9
R	Fireclay	31·0	31·2	—	31·0
S	China clay	30·5	—	30·8	30·8

Porosity.—Table 7 gives the values of the porosities of the various materials fired at cones 14, 16 and 19. From the results the blocks may be divided into two groups; one in which the porosity varies irregularly with the firing temperature, and a second in which it varies regularly. A, B, D and E belong to the former, and H, I, K, N, O to the latter. The two groups correspond roughly to those in the case of the apparent specific gravities, but there are exceptions in each case.

After-expansion.—The standard test specified by the Institution of Gas Engineers consists in heating a brick of known size to cone 12, maintaining it at that temperature for two hours, and then, after allowing to cool, measuring the increase in size. As the blocks used in the present experiments were much smaller than the ordinary silica brick the temperature to which the material was heated was cone 16. The blocks were measured, before and after heating, with a vernier gauge reading to ·001 inch. The percentage linear expansion is given in column 3 of Table 8. Another set of samples was then tested

TABLE 8.—SHOWING THE RELATION OF THE MEASURED "AFTER-EXPANSION" TO THE CALCULATED "TOTAL AFTER-EXPANSION."

		1 True sp. gr. after heating to Cone 26	2 Calculated Linear Expansion after heating to Cone 26	3 Measured Linear Expansion after heating to Cone 16	4 Ratio of 2 to 3
A	CaO	2·34	3·71	·47	7·9
B	MgO	2·34	4·30	·48	9·0
C	Al_2O_3	2·34	5·28	·38	13·9
D	Fe_2O_3	2·34	4·11	·50	8·2
E	Fe_2O_3+C	2·35	4·38	·52	8·4
G	$CaO+MgO$	2·34	4·02	·52	7·7
H	$CaO+Al_2O_3$	2·34	5·23	·22	23·8
I	$CaO+Fe_2O_3$	2·33	3·27	·25	13·1
J	$CaO+Fe_2O_3+C$ ...	2·33	3·05	·23	13·2
K	$CaO+TiO_2$	2·34	5·07	·37	13·7
L	$MgO+Al_2O_3$	2·34	4·62	·50	9·2
M	$MgO+Fe_2O_3$	2·34	4·49	·67[1]	6·7
N	$MgO+Fe_2O_3+C$ ...	2·33	4·38	·46	9·5
O	$Fe_2O_3+Al_2O_3$ ...	2·35	4·32	·45	9·6
P	$Fe_2O_3+Al_2O_3+C$ ...	2·34	4·35	·30	14·5
Q	$CaO+Fe_2O_3+TiO_2$ ...	2·34	3·98	·47	8·5
R	Fireclay	2·34	3·77	·31	12·2

[1] This brick cracked on heating; hence the high value.

by heating to cone 26 and maintaining them at that temperature for about 4 hours. (In each case all the samples were fired together.) Owing to the rapid heating and cooling several

of the blocks developed cracks, which precluded a direct determination of the expansion by measurement. The expansion, however, can be calculated provided the apparent specific gravities of the blocks, before and after heating, are known. The apparent specific volumes (the apparent volume occupied by 100 gms.) are given in columns 1 and 2 of Table 9, and the

TABLE 9.—SHOWING THE CALCULATED AND APPARENT AFTER-EXPANSIONS OF BRICKS HEATED TO CONE 26.

		1 Sp. vol. before test	2 Sp. vol. after test	3 Percentage Increase of Volume	4 Percentage Linear Increase	5 Measured Linear Increase	6 Ratio of 5 to 4
A	CaO	57·1	63·7	11·56	3·71	4·64	1·25
B	MgO	56·5	64·1	13·45	4·30	4·34	1·01
C	Al_2O_3	58·1	67·8	16·69	5·28	7·24	1·37
D	Fe_2O_3	58·1	65·8	13·25	4·11	4·28	1·04
E	Fe_2O_3+C	57·5	65·4	13·74	4·38	4·43	1·01
F	TiO_2	57·8	71·1	22·64	7·08	7·02	·99
G	CaO+MgO ...	58·9	66·3	12·56	4·02	4·17	1·04
H	CaO+Al_2O_3 ...	57·5	67·0	16·52	5·23	5·43	1·04
I	CaO+Fe_2O_3 ...	55·6	61·3	10·14	3·27	3·47	1·06
J	CaO+Fe_2O_3+C ...	57·1	62·5	9·46	3·05	3·82	1·20
K	CaO+TiO_2 ...	57·5	66·7	16·00	5·07	5·12	1·01
L	MgO+Al_2O_3 ...	58·5	67·0	14·53	4·62	4·78	1·04
M	MgO+Fe_2O_3 ...	57·5	65·6	14·09	4·49	4·65	1·04
N	MgO+Fe_2O_3+C ...	57·5	65·4	13·74	4·38	4·84	1·09
O	Fe_2O_3+Al_2O_3 ...	59·9	68·0	13·52	4·32	4·51	1·06
P	Al_2O_3+Fe_2O_3+C ...	59·9	68·6	13·62	4·35	5·14	1·18
Q	CaO+Fe_2O_3+TiO_2	56·9	64·0	12·44	3·98	3·97	1·00
R	Fireclay	58·9	65·8	11·71	3·77	5·71	1·51
S	China clay ...	57·1	68·0	19·09	5·99	6·74	1·13

volume and linear expansions calculated therefrom in columns 3 and 4 of the same table. In cases where cracking has occurred during heating it is best to break off a piece which has no visible cracks and make the determination on that. Of course very fine cracks will act as pores and will tend to diminish the apparent specific gravity, but the error thus introduced is probably slight. Column 1 of Table 8 gives the true specific gravity of the blocks after heating. As the values are all practically the same, and approximate to the specific gravity of cristobalite, it may be assumed that most of the quartz has been converted. Hence it seems feasible to take the after-expansion at cone 26 as indicative of the total expansion of the material during conversion. Column 4 of Table 8 gives the ratio of the after-expanson at cone 26 and cone 16, and it will be seen that this ratio varies from 6·7 to 23·8. Hence the test carried out at cone 16 may not give even an approximate idea of the expansion which will occur during

use. In order to get such an idea it is necessary to heat either to a much higher temperature than cone 16, or for a more prolonged period. Bricks H and J, heated to cone 16, have very similar expansions; when heated to cone 26, that of H is nearly twice that of J. Again, the after-expansion of A at cone 16 is considerably higher than that of C, but the expansion of the latter at cone 26 is much greater than that of the former. Where the materials being tested are of similar composition, however, the test carried out at cone 12 or 14 will probably give a fair indication of the expansion likely to occur in use. Even with the widely different types of bonds used in the present instance, the ratio of the expansions at cone 16 and cone 20 approximate to either 9 or 13, H and M being the only examples which diverge widely from one or other of these values.

The reason for the discrepancies is fairly obvious. Some bonds convert the quartz to its high temperature forms at a greater rate than others. On the basis of the theory that the conversion of quartz in silica bricks is due to the solution of the quartz by the silicates forming the bond and precipitation of the dissolved silica as cristobalite,[1] the rate of conversion, under standard conditions of temperature, grain-size of quartz, etc., will depend on two factors, the solubility of the quartz in the molten silicates and the viscosity of the latter. Where the viscosity is high, the rate of solution will be relatively low, and hence the rate of conversion will be low. Since the after-expansion is mainly due to the change of volume during the conversion, a factor which influences the latter will also influence the former. Hence, where the rate of conversion is rapid at the temperature of the test, the after-expansion is high; where the rate is slow, the after-expansion is low. It might be argued that the bricks ought to be tested at the temperature at which they are going to be used. In that case the heating should be prolonged till the conversion is nearly completed; in practice, of course, this would be impossible for temperatures in the region of cones 12 to 16. The important point is to determine the total expansion, and hence the brick should be tested at such a temperature as will give approximately total conversion in a comparatively short time; so far as the bricks under consideration are concerned, cone 26 is sufficiently high. The heating and cooling, however, would have to be conducted slowly, so as to avoid the danger of spalling.

With regard to the results, the smallest expansions are found in the bricks in which the bond is a mixture of lime and iron

1 Trans. 17, 147, 1918.

oxide, while the next lowest occur in those in which these oxides are used separately. Magnesia gives a higher expansion than lime when used alone, and the same holds for combinations of these with alumina and iron oxides. Alumina and titanic oxide both give high values, but, if another oxide is present in addition, the values are much lowered. The expansion in the case of the fireclay bond is low. The presence of carbon does not alter the after-expansion very much, but it is significant that in three out of the four cases tried, the bond containing carbon gives slightly lower values than the corresponding carbon-free bond.

Spalling.—The ordinary method of conducting spalling tests, by alternately heating and cooling the bricks rapidly between fixed temperature limits and then determining the loss of weight is decidedly unsatisfactory. McDowell[1] has proposed a method by which the relative tendency to spalling is measured by the percentage change in the modulus of rupture after heating to 600° C. and cooling in air; the results obtained were fairly satisfactory. The data in Table 9 might also be used to give the relative spalling tendency. When the blocks were heated to cone 26 and cooled rapidly, fine cracks occur, but the brick retains its external rectangular shape. The apparent expansion can be obtained by direct measurement, and the ratio of this to the expansion, calculated from the specific gravity determinations, might be used to indicate the relative amount of spalling. Of course, a temperature considerably lower than cone 26 might be used. In conducting tests all the bricks to be compared would be heated and cooled together.

The ratio of the expansion as measured to the expansion as calculated is given in column 6 of Table 9. In general the bonds containing magnesia give somewhat lower values than those containing lime. The addition of carbon to the bond seems to increase the ratio as the values for D, I, M and O are lower than those for E, J, N and P respectively. The values for alumina and fireclay are high while those for the bonds containing TiO_2 are low.

Refractoriness.—The tests for refractoriness were carried out by the usual method, the results being collected together in Table 10. The test pieces were subsequently sectioned and examined microscopically.

1 *Bull. Amer. Inst. Min. Eng.*, **119**, 2047, 1917.

TABLE X.—SHOWING THE RESULTS OF REFRACTORY TESTS.

		Refractory Test Cone	Approximate Equivalent Temperature°C.	Remarks
A	CaO	33	1730	Squatted rapidly
B	MgO	33 -34	1730—1750	Squatted
C	Al_2O_3	36	1790	Did not squat
D	Fe_2O_3	36	1790	,, ,,
E	Fe_2O_3+C	36	1790	,, ,,
F	TiO_2	35	1770	Did not squat
G	$CaO+MgO$	34	1750	Squatted
H	$CaO+Al_2O_3$	35	1770	,,
I	$CaO+Fe_2O_3$	34	1750	,,
J	$CaO+Fe_2O_3+C$ ...	33—34	1730—1750	,,
K	$CaO+TiO_2$	34	1750	Squatted slowly
L	$MgO+Al_2O_3$	34	1750	,, ,,
M	$MgO+Fe_2O_3$	35	1770	,, rapidly
N	$MgO+Fe_2O_3+C$ ...	35	1770	,, ,,
O	$Fe_2O_3+Al_2O_3$ ...	35	1770	Did not squat
P	$Fe_2O_3+Al_2O_3+C$ ...	35	1770	,, ,,
Q	$CaO+Fe_2O_3+TiO_2$ ...	33—34	1730—1750	Squatted
R	Fireclay	36	1790	Did not squat

A. This softened to a glass at cone 33. The viscosity was low and the glass was easily fluid at cone 35. The fragments apparently fused.

B. This melted to a fluid glass at cone 33—34, and the rock fragments were largely dissolved at cone 36. Micro-examination showed both fragments and matrix to have fused to a vesicular mass, the vesicles, however, being filled with minute crystals.

C. The material apparently melted at cone 36, but the high viscosity prevented any squatting and hindered the solution of the rock fragments. Micro-examination showed the fragments to be fused to a considerable extent with patches of cristobalite in the cores. Spherulitic aggregates of tridymite (?) occur round the vesicles. The matrix consisted of glass with numerous sillimanite needles.

D and E. The pieces softened at cone 36 to a very viscous mass. The original shape persisted, except that the sharp angles were rounded, while the rock fragments remained distinct. Under the microscope the fragments were seen to consist partly of glass and partly of spherulitic cristobalite. Their outlines could be distinguished by the fact that they contained numerous gas cavities. The iron oxide was mainly segregated in the matrix, which was also partly glass and partly crystalline.

G. The piece melted to a grey glass at cone 34, the melt being sufficiently mobile for partial solution of the rock fragments to occur at cone 36. A microsection showed the whole piece to be mainly glass.

H. The piece softened at cone 35 to a black glass which squatted slowly. The fragments were not fused unless round the margins.

I. The piece melted at cone 34 to a dark-grey glass. The quartz of the larger fragments had been altered to cristobalite, but the shape of the crystals suggested that tridymite may have occurred as an intermediate stage.

J. The softening point was cone 33—34. The piece was very similar to I.

K. The piece softened to a viscous grey glass at cone 34, but the fragments did not melt to any great extent.

L. The piece melted to a black glass at cone 34. The squatting was slight and the larger fragments were not fused.

M and N. The pieces melted suddenly at cone 35 to a black glass which squatted readily. At cone 36—37 most of the fragments had fused and lost their individuality. A microsection showed both the fragments and matrix to be mainly glass, the iron compounds being segregated in the matrix. The vesicles were filled with crystals of magnetite and fayalite.

O. The sharp edges began to be rounded at cone 35, but the piece did not squat, nor were the fragments dissolved at cone 36.

P. The behaviour was similar to that of O, the rounding of the sharp angles occurring at cone 35, but there was no squatting even at cone 36—37. Micro-examination showed the matrix to have melted to a brownish glass while the margins of the fragments were indistinguishable and had been dissolved by the matrix. The cores, however, still showed cristobalite.

R. The piece softened to a grey glass at cone 36+ but did not squat. The fragments had apparently commenced to fuse but had not mixed with the matrix to any extent.

In the case of those blocks which contained lime or magnesia as one constituent the softening is due to the fusion of the mixture of silicates and fine-grained free silica in the matrix. Where the bond consists of alumina or iron oxide, or a mixture of the two, the matrix and rock fragments seem to fuse simultaneously and the softening point of the piece is practically the same as that of silica. The absence of squatting is due to the high viscosity of fused silica. Fireclay acts in a very similar way.

In three out of four cases carbon had no appreciable effect on the softening point; in the fourth, where the bond was a mixture of lime, ferric oxide and carbon, the softening point was one half cone lower than in the case of the corresponding carbon-free block. The results of these refractory tests will be further discussed in the second part of this work, in connection with the refractoriness under load.

DISCUSSION.

Dr. ORMANDY:—It is unfortunate that these very valuable, eminently scientific papers, containing many tables, are not conducive to lively discussion. The point raised by the speaker as regards the behaviour of iron is of the greatest importance. I was under the impression that Fe_2O_3 in contact with silica was converted into the ferrous condition when strongly ignited. Experiments made on mixtures of finely divided silica and fine Fe_2O_3 heated in an oxidizing atmosphere to over 1,300° C. resulted in the formation of segregations of ferrous silicate, and yet the speaker has referred to the effect of iron present throughout in the ferric state.

Another interesting point raised by the speaker is his reference to the behaviour of various bonds. Certain of the mixtures consisting essentially of silica with a small amount of bond squatted readily, while others seem to melt as a whole. The lecturer attributes this difference of behaviour largely to the difference in viscosity of the bonding material. This point is of great practical importance, as it will probably have serious effect on the load carrying capacity of the bricks much below the melting point, and it will be interesting to know the results of further experiments in this direction. Unfortunately such experiments are slow to carry out, are expensive and necessitate much work to get sufficient information to draw deductions. Certain experiments which I carried out at a large glass works which bear on this subject by analogy may be of interest. A very soft pitch, obtained by mixing hard pitch with creosote oil, was melted and so much free silica added as produced a thin pasty mass. To this was added Fontainebleau sand until the mixture tended to become too thick. Further additions of Oporto gravel and coarse broken flint were then made until the mass would just pour. The resulting paving bricks had a crushing strength about equal to that of a good Staffordshire blue brick, and this in spite of the fact that the bond which formed a small percentage of the total mass was comparatively free flowing. This behaviour can only be attributed to the fact that the surface of the mineral was so great that only molecular layers of the viscous material came into question, and under these conditions it is possible that the frictional resistance to shearing of the pitch film is very much greater. It is possible that interesting and valuable results might be obtained by working on such mixtures, as these could be carried out rapidly at ordinary temperatures and the results might have a bearing on the problems met with in silica brick making.

Mr. T. ARTHUR ACTON:—I entirely agree with the remarks of previous speakers. We are all very much indebted to Dr. Scott and shall hope to see further research in this line by him. It is one of the main objects of our Society to encourage pure research work of this nature—only having seen the paper to-day I should like to study it further before venturing any remarks thereon. It may, however, be well to remind members that this paper is in a way academic, the results having been obtained from chemically manufactured materials, and it may be some of the results obtained would work out differently if ganisters or quartzites were tested in a similar way. The use of veined quartz has not been satisfactory in

the manufacture of silica bricks. Pure vein-quartz does not seem to give the mechanical strength necessary in a silica brick. In Dr. Scott's experiments there is an enormous fund of information which will require carefully thinking out, and the tabulated results will be of great value to the manufacturer of silica bricks. I hope Dr. Scott will be encouraged by our appreciation of this work and will have the time and opportunity given him to continue his interesting studies on quartz-conversion.

With regard to the conditions of finished materials. The addition of finely ground silica seems to add materially to the strength, and helps conversion in the manufacture of silica bricks, but grinding raw ganister or quartzite to give a percentage of anything from 25—30 per cent. of flour adds much to the cost of production; whether a calcined vein-quartz ground to flour would give the same result as ganister or quartzite so ground does not seem to have been proved—generally the method of grinding and grading as practised in this country seems a little primitive—the grinding plant for silica brick making seems to require the consideration of the scientific engineer.

Dr. J. E. STEAD:—The only remarks I have to make with regard to the very interesting research by Dr. Scott is one of astonishment of the enormous amount of energy and work that has been put into it. A few of us have made similar experiments, and I think we may accept the result as true and put them in a place to which we can always refer.

The author must be complimented upon what he has done. I must say that I am very delighted to find that so many of our young men are going ahead and not going to sleep, and The Ceramic Society is carrying on with great vigour and energy.

Dr. SCOTT:—With reference to Dr. Ormandy's remarks, there is, so far as I know, little evidence in favour of the view that ferric oxide, in the presence of silica, is reduced on heating in an oxidizing atmosphere and reacts with the silica to form ferrous silicate. Whilst the equilibrium between the iron oxides and silica has not been systematically investigated, there is considerable evidence against any such reduction. In the present case microexamination showed that most of the iron after firing was present as magnetite, and the only blocks in which fayalite was present were those which contained carbon. Fayalite was also observed in some of the fused blocks after heating to cone 36, but even there it was only present in the

neighbourhood of the vesicles, and there is little doubt but the gases of the vesicles have played a considerable part in the formation of the ferrous silicates. The presence of magnetite and the absence of silicates of iron in so many granites is also strong evidence against such a reaction.

Dr. Ormandy's suggestion that the "softening" phenomena of silica bricks might be tested by analogy is interesting, and such tests might yield very profitable results. The strength of silica bricks at high temperature must be largely due to the resistance to shear of the amorphous bonding material, and this, of course, will vary with the viscosity and the thickness of the layers separating the rock fragments.

With reference to Mr. Acton's remarks it might be pointed out that in order to determine the effect of each oxide it was necessary to use as pure a quartz-rock as possible, vein-quartz being the obvious material. The presence of a constant proportion of impurities—generally over 2 per cent—renders the use of ganister, etc., impossible for such a series of tests. The question of grading is one to which very little attention has been paid; the ideal grading, if the material could be crushed economically, would be that which gave maximum conversion combined with maximum strength.

XXXII.—Recent Research on the Bone China Body.

Communications from the Clay and Pottery Laboratory, Stoke-on-Trent.—No. 91.

By J. W. Mellor.

Introduction.

Of all the different kinds of pottery bodies known to man, I believe that the so-called bone china body is the most remarkable. Bone-ash, you will remember, is mainly a compound of calcium, phosphorus, and oxygen. Two solids, one gas. Phosphorus is a very tricky solid, and in the phosphorus works it is extracted from bone-ash or related compounds. You can call the compound calcium phosphate, normal calcium phosphate, or phosphate of lime—it does not matter which.

From the time the raw materials enter the blunger, to the time the finished ware leaves the enamel kiln, the bone-ash is the seat of a number of extraordinary chemical changes which make the chemistry of the body unique. So far as I know there is nothing to approach it in the whole range of ceramics.

It is still more wonderful how manufacturers instinctively keep clear of many of the incidental dangers, and successfully pot so extraordinary a body. I know that many attempts to make this body in other countries have met with disaster, and I do not wonder. I believe that the trials and failures which are ahead of those who are taking up the manufacture of hard porcelain are as nothing compared with what would follow if we had been hard porcelain manufacturers and were to attempt to make bone china.

In a way I should be inclined to funk the ordeal of facing a body of manufacturers on this subject were I not convinced that one can get so familiar with a process that a kind of blindness supervenes and prevents our seeing the obvious. I feel sure that, although this body was very successfully potted long before yours truly was in short trousers, there are many peculiarities about it which require a sound knowledge of the chemistry of the bone china body in order to reduce losses and maintain a high standard of quality; otherwise expressed, ignorance makes the pocket light.

I have had the bone china body under observation over a dozen years, and, going back in recollection, I think we can safely say that Longton has itself worked out the chemistry of what is peculiarly its own body. You will find, either expressed or implied, almost all the essentials in a paper published in the TRANSACTIONS of The Ceramic Society for 1905. It is by the Sherlock Holmes of the potbank. I allude, of course, to Mr. Bernard Moore. I feel positive that it would well pay the Longton china manufacturers to have that paper reprinted and distributed broadcast in the place of its birth. It is one of the very best of the papers in the TRANSACTIONS of our Society. I am also greatly indebted to "Mr. Bernard" for his help and advice in the preparation of this paper. Several students have also done a great number of experiments, the results of some of which I am able to place before you. With these acknowledgments I am now free to tell the story in a straightforward way.

I wish I could impart to you the intense pleasure which I have derived while the chemistry of the bone china body has been developing to its present state. I will do my best to interpret the highly technical language of the laboratory into that of the workshop, but there is just one part where I shall try to extend that of the workshop so as to give it a wider range.

The Slip House.

Starting with the sliphouse. You know, of course, that Cornish stone owes its fluxing qualities mainly to the felspar which it contains; you know also that in the wet grinding of felspar, a slow reaction takes place between the felspar and the water. This reaction is not clearly understood, but so far as I can see felspar and water produce among other things china clay, and water glass. The reaction goes on slowly during the grinding of the felspar, so that clay, and possibly silica, deposit as a thin film on the surface of each grain; the water glass passes into solution. As a result, the water in which felspar is ground becomes alkaline, and acquires the viscid "ropiness," so to speak, characteristic of solutions of water glass. The great tendency of felspar to set during the grinding, when the pans are stopped for any length of time, is possibly due to the cementing action of the water glass. A similar action goes on with the contained felspar during the grinding of Cornish stone, but the action is largely masked by the accompanying clay and quartz in the stone.

The action with felspar is very slow; there is also a reaction between water and bone-ash which is also slow, but I believe faster than with felspar. The harder the calcination of the

bone-ash, the slower the action. The reaction with bone-ash forms soluble acid calcium phosphates or even phosphoric acid itself. As a result of these changes the body materials acquire a far greater plasticity than they would otherwise possess. The plasticity of these materials is largely dependent on their past history. The longer the materials have been associated with water during their preparation, the more "buttery" the body in the workshops.

Whenever the process of preparing the body is speeded up there are complaints in the workshops that the body is becoming short. The older potters tell me that when filter-presses were displacing slip-kilns, there were various complaints about the shortness of the body. You can also see how the body works very badly when the attempt is made to cut out the slip-kiln in the preparation of the bone. The warmth of the slip-kiln also hastens the action between the water and the bone-ash. If this explanation be all the story, I think we can see some likely ways of eliminating the slip-kiln without interfering with the subsequent plasticity of the body. The phenomenon also has a possible bearing on the blistering of old ware. All this, however, is work to be done in the future.

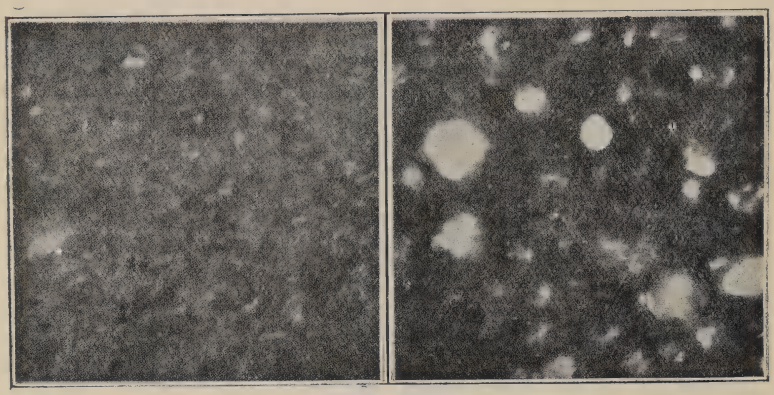
You cannot mature the plasticity of a bone china body like you can that of an ordinary clay body, because the organic matter, which is not all destroyed in the calcination of the bone, begins to putrefy, the body becomes fetid, and the slip becomes very "blibby" owing to the development of gases during the putrefaction. Of course, antiseptics like formaldehyde can be used to prevent putrefaction, but the plasticity of a bone china body is so low and so very sensitive to the presence of foreign agents that some discrimination would be required.

The Swelling of Over-Fired Bodies.

I now propose to look at what is taking place in the biscuit oven near the finishing temperature. The bone china body contains bone-ash, clay, quartz, and felspar. The quartz, felspar, and a little clay come in with the stone. Suppose the first ring in one quarter of the oven is very slightly over-fired, we may find that of two bungs of tea plates made in the same moulds in precisely the same way and fired in the same saggar, the plates in one bung are slightly larger than those in the other. We know what a tremendous contraction the bone china body undergoes in firing, and we should naturally expect the smaller plates would be found on the hottest side of the saggar. The greater the temperature, the bigger the contraction. This is true up to the finishing temperature, after which just the

opposite is nearer the truth. The greater the temperature the larger the body. I remember being puzzled with this. I therefore cut two thin slices from a plate from each of the two bungs. Photographs of the two are shown side by side in Fig. 1. Under a low power magnification, the body of the smaller plate looks like an opaque glass. The harder-fired plate has begun to develop little cavities in its interior which cause it to swell. Where does the gas come from? We cannot imagine bubbles being blown in the middle of a body in this way without the development of a gas in the interior of the body.

Let us look in another quarter of the oven also over-fired, but a little more than was the case with the flat ware. Here are two boxed cups, stuck together fast; one cup is bulged



Normal bone china. Hard-fired bone china.

Fig. 1. Difference in interior of hard and properly fired bone china × 50.

inwards a little. We can understand the inward bulge, because at the temperature of the biscuit oven the air in the cups is very attenuated or thin, being very much expanded by heat. The body is fairly soft at the top temperature of the biscuit oven, otherwise it would not be necessary to be so careful with the placing. We are supposing that the cups are sealed by their fusing together at their brims, then, as soon as the oven begins to cool, the air wants to get back into the interior of the cups, and it presses on the outside thus causing the inward bulge.

We break open the cups, and we hear a "pop," this is due to the sudden rush of air inwards. There is also a kind of "sulphurous" smell in the interior of the cup when first

opened, the smell really recalls not sulphur but phosphorus. Whence comes the phosphorus? The only possible source of this element is the bone-ash itself. Here then is evidence that the bone-ash commences to break down at ever so slight a temperature above what the fireman regards as a good finish.

Remembering that there is only about 20° difference between the temperature of our bodies and the temperature of this room, if anyone outside the district were shown a china biscuit oven being fired in all its crude and primitive splendour, and were told that if the fireman goes 20° above his right finishing temperature the ware would be spoilt, then, I feel sure that in making an allowance for poetic licence, the visitor would add another 100° to our statement. I think the 20° would not be far from the truth.

A visit to a phosphorus works would now be instructive. We find that phosphorus is made by calcining what really amounts to a mixture of charcoal, bone-ash, and quartz; if the charcoal be omitted, a rather higher temperature is needed. This point is important. In pottery firing the presence of charcoal would be equivalent to a reducing atmosphere—too little air, too much smoke. The development of the gas bubbles in the body during the oven firing of bone china indicates the beginning of the very same reaction which takes place in the retorts during the manufacture of phosphorus, the only essential difference is that the phosphorus manufacturer fires at a still higher temperature and takes precautions to prevent the oxidation of the phosphorus.

The Behaviour of the Iron in the Body.

There is not very much more than one or one and a half per cent. of iron in a bone china body, but that little behaves in a very queer way, since when the phosphorus breaks loose from the bone-ash, the iron seems to be one of the very first things which it attacks and converts into phosphate of iron; bone-ash is mainly phosphate of lime, or rather calcium phosphate, so that the "phosphate," so to speak, divorces the lime and marries the iron.

Phosphate of iron occurs naturally as the mineral vivianite. This mineral can be obtained white, but it rapidly changes to a bluish-green colour on exposure to the oxygen of the air, and after prolonged action of the air it is covered with a brownish-red crust. Consequently, if we find in a bone china body indications of the formation of greenish-blue, blue, and brown colours, there is a probability that the chameleonic iron phosphate is making its presence evident.

I have shown that the liberation of phosphorus from the lime of the bone-ash is facilitated by the presence of carbon or of an equivalent reducing atmosphere, and therefore, other things being equal, we may expect the divorce of the phosphate from the lime and its marriage with the iron to take place in those parts of the oven which are least ventilated, *e.g.*, round the well-hole, or in a quarter which has too little air. These are the parts of the oven most likely to develop this type of blue china. I believe Cotton's system of firing had to be given up in bone china firing because of its tendency to produce blue china by reducing the free circulation of air at a critical stage in the firing. You can make the blue china quite readily by enclosing some charcoal or organic matter in the saggar with the china while it is being fired. You can also use bone with a relatively small amount of carbonaceous matter and get blue china. The presence of carbon, and insufficient air in the oven favour the formation of iron phosphate by enabling the transformation to take place more quickly at a lower temperature than it otherwise would do. Steam from damp saggars, etc., may act in the same way as a kind of barrage preventing the access of air to the ware at the right time.

The Reducing Atmosphere Theory offers only a Partial Explanation of the Facts.

The theory I have just outlined seems very plausible, and yet there are many contradictions. It would be easy to successfully defend the thesis that the theory is not right. For example, the very best bone is sometimes rather higher than the average in carbon, for it is calcined at a rather low temperature and it is used for making the very best china. It is easy to show that you can get the blue china with bone-ash practically free from carbon and fired all the time in an oxidizing atmosphere.

Here then is one of those delightfully common predicaments which make our industry so peculiarly fascinating. If we choose, we can toss up for sides, and, following the example set up by some of our politicians and some of our designing artists, try to squash the opposite side by a disputation of wits in the "Sentinel." This kind of research offers no attractions to the seeker after truth. We must hold tenaciously to the fundamental principle that one obstinate little fact will demolish the most plausible theory. We have no use for beautiful theories woven with gossamer threads of so fine a texture that they cannot bear contact with hard material facts. Consequently, instead of scholastic argument, let us return to the sliphouse. It does not follow that because the theory is but partially

successful it is altogether wrong; but it does follow that if it be not wrong it requires to be modified and adjusted so that it can be made to include the recalcitrant fact or facts.

In illustration, some of the apparent contradictions are explained by the fact that bone-ash may contain carbon under such conditions that it does not burn out readily. This form of carbon is a bad mischief-maker. Another form of carbon burns out of the body readily, and gives very little trouble in the biscuit firing, presumably because the carbon is gone before the temperature gets near to the decomposition point of the bone-ash. If the vitrification of the body sets in before the carbon has all burnt away there is likely to be subsequent trouble. I believe that the particular form of the carbon in the bone-ash is largely determined by the way the bone is

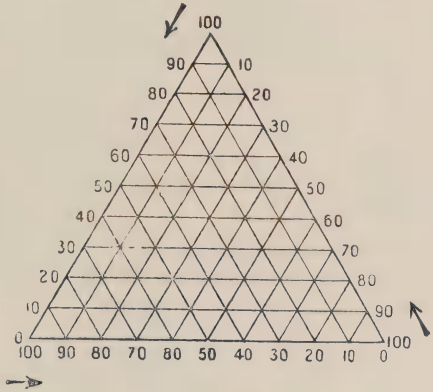


Fig. 2. Standard Triangular Diagram.

calcined. If the temperature is rapidly raised to a comparatively high point the slow-burning dangerous form of carbon appears.

Representing Results on Squared and Triangular Paper.

You are of course familiar with the use of ordinary squared paper for representing two varying quantities—the fluctuations in costs of material from week to week, and so on; you know how very useful is this mode of representation for enabling the mind to quickly grasp the meaning of the figures. So under certain conditions it is possible to represent three variables by means of a diagram, and with a little practice the mind can grasp the meaning of the three variables almost as easily as it can variations of two.

In the bone china body we have three materials: bone, stone, and clay. Many a time the students have made up all possible bodies with 20 per cent. variations. The composition of these bodies are indicated in the first three columns of Table I along with the colour of the biscuit trials.

TABLE I.

No. of Trial	Per cent. of Ingredients			Colour of Trial Biscuit
	Clay	Bone	Stone	
1	100	0	0	Cream
2	80	20	0	Brown
3	80	0	20	Yellow
4	60	40	0	Pink
5	60	20	20	Light Brown
6	60	0	40	Cream
7	40	60	0	Green
8	40	40	20	Pale Green
9	40	20	40	Yellow
10	40	0	60	Slight Brown
11	20	80	0	Brown
12	20	60	20	Colour very slight
13	20	40	40	,, ,, ,,
14	20	20	60	,, ,, ,,
15	20	0	80	Tinge of Green
16	0	100	0	White
17	0	80	20	,,
18	0	60	40	,,
19	0	40	60	,,
20	0	20	80	,,
21	0	0	100	,,

It would require a very great effort and a very great concentration to get a dim idea of the meaning of these numbers if we depend solely upon the table. Let us construct a triangle with sides of equal length, and draw lines parallel to each of the three sides so as to divide the plane into tenths. If the apices of the triangle represent respectively stone, bone, and clay, then, every possible mixture can be represented by a point on or in the triangle. The vertical distance of a point on the line just below the stone apex represents all bodies with 90 per cent. stone, the next line 80 per cent. of stone and so on. Similarly with bone and clay. All the bodies indicated in Table I now find a place on the triangle. The numbers on Fig. 3 correspond with those in the first column of Table I. By travelling in the direction of one of the apices of the triangle the proportion of that constituent is increasing, and conversely.

Fig. 3.—Colours of Bone China Trials after the Biscuit Firing.

Fig. 4.—Colours of Bone China Trials after the Glost Oven Firing.

By arranging the biscuit trials on the triangular diagram we obtain Fig. 3, which shows the relation between colour and composition. The standard bone china body for reference is shown in the little circle out of the regular sequence. May I impress upon you how limited is the range of white bodies. Of all the possible bodies the potter has selected the few in the region, excepting on the narrow line drawn from the bone apex towards stoneware bodies made from clay and stone, there are some queer difficulties. Note the extraordinary variety of tints developed. Note the greenish-blue colours of the 40—60—0, and the 40—40—20 and 20—60—20 bodies. When I arrange a triad of numbers in this way, the order: clay, bone, stone, is to be understood. These colours, I think, establish the fact that we can get the greenish-blue colour at the ordinary temperature of a china biscuit oven, altogether apart from the atmosphere and of carbon. These results have been also confirmed by trials with precipitated calcium phosphate in place of bone.

The Danger Zone.

The general fact stands out prominently that there is a bigger margin of safety with variations in the proportion of bone than there are in the proportion of either stone or clay, and the greater the distance from the stone apex (that is, the smaller proportion of stone), and the nearer to the clay apex (that is, the greater the proportion of clay), the greater the tendency to produce the blue or brown china. In forming this triangle good commercial samples of bone, stone, and clay were used. Each type, of course, has its own particular triangle; a more vitreous variety of clay, for instance, will favour the stone, but I do not now intend to side-track into details of this character. It will be sufficient to emphasize the fact that the greater the proportion of clay, or the dryer the character of the stone, the greater tendency to form blue china. Otherwise expressed, the presence of a high proportion of alkalies hinders the transfer of "phosphate" from the bone-ash to the iron.

The natural inference follows that to keep as far from the danger zone as possible the bodies should approach closer to the stone apex, or a softer stone should be used; but we can have too much of a good thing, for, by raising the stone, we pass from Scylla to Charybdis, from the frying pan to the fire. The bodies now blister or bloat. Note we are still in the vicinity of the ideal or perfectly balanced body, and yet on the one side we pass into the region where the bone and

iron are in conflict, and on the other side into the region where the whole structure collapses owing to the fluxing action of the stone. There are troubles to the right and troubles to the left, behind, and before.

This sort of thing makes one realize how delicately the ideal body is balanced over the pit of disaster; the balance is indeed so very delicate that the mere change from a soft to a harder variety of stone may give a perfect body a tendency to form blue china; or the converse change from a hard to a softer variety may make a perfect body liable to blister. Again, a variation in the proportion of water in the same variety of stone may also upset the balance, and an enormous amount of blue china must have been the result of assuming that the stone has, say, 10 per cent. of water, when it really contains 20 per cent. or more. Similarly, if the clay be weighed out dryer than usual, the same result will follow. I have known cases where the explanation here given has been dubbed all nonsense because the fault has disappeared when a new supply of clay has been introduced. It is forgotten that if precautions be not taken with a new supply of clay, less clay and more water is weighed into the body when the new batch of clay is wetter than that which has partially dried in the store bins. The variation in the proportion of water in bone does not matter so much, because, as indicated above, there is a bigger margin of safety with bone than with stone or clay.

Still further, the balance is so exquisitely sensitive that the same body may produce all three varieties: blistered, blue, and perfect china. The blistered body signifies too much stone or too soft a stone, and the blue china too little or too dry a stone. If the sifting ark be not large enough to hold all the charge from the rough pot and slip be taken off to the filter press before the rough pot is emptied, it follows that the stuff easiest blunged in the rough pot will pass on first, and that the ware will blister, while the clays coming last will produce blue ware. When Sherlock Holmes read his valuable paper, he estimated that "the Longton manufacturers must have lost £50,000 in 25 years from faults produced because the ark which follows the rough pot was too small to hold all the charge." The same result obtains when the filter presses are at work before the blunger is emptied.

The Browning of China in the Enamel Kiln.

The subsequent history of the colour of the bodies in the glost oven and the enamel kiln is well illustrated by the corresponding diagrams, Figs. 4 and 5. Perhaps the most interesting

Fig. 5.—Colours of Bone China Trials after the Enamel Kiln Firing.

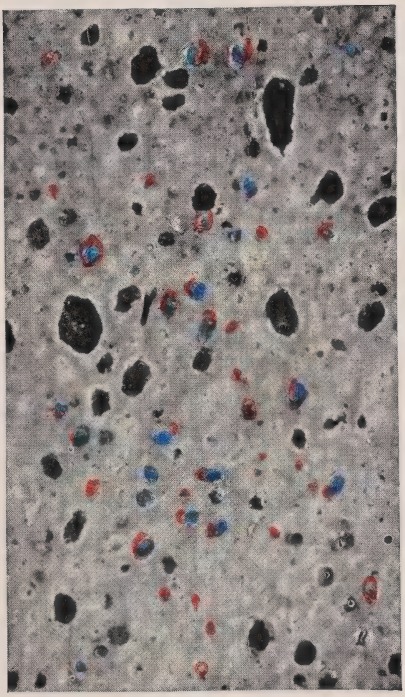


Fig. 6. Bone China Body, showing Blue Crystals with Reddish-Brown Crusts. x 50.

part is in the region corresponding with too hard a stone. Here the blue china is in such a critical condition, after passing the glost oven, that it may oxidize in the enamel kiln and produce brown stains. I have previously indicated the relation between the blue and the brown china, and even white china when the white contains unoxidized white iron phosphate. We regard blue phosphate as partially oxidized white phosphate, and brown china as the end product of the oxidation.

The condition of the white iron phosphate in the body may be so sensitive that it oxidizes to the brown form merely by exposure to the air. The brown spots with the 40—40—20 body on exhibition are even now gradually extending, so that it looks as if, in time, the whole body will be brown, not blue. You will also see that in the cracked cup, which is here exhibited, the white or blue phosphate has oxidized along the cracks, since it is only here that the air can readily get into the interior. This makes the body look as if it were stained with tea or something, whereas it has never contained a liquid at all. We can therefore get brown china merely by exposing the body to the air, and I have heard of cases where ware has been returned to the manufacturer owing to the discoloration produced by exposure in the shop window. The manufacturer has argued that it is impossible for bone china to discolour in this way, and the dealer has maintained that the ware has not been used at all; we can now see that the discolored china is the natural condition of an unstable body produced with too little stone or with too dry a stone. When the iron phosphate is in the sensitive condition, ready for oxidation, the air can penetrate but slowly into the body and oxidize the white or blue phosphate to the brown form. Hence, it may be years before the browning becomes apparent.

There is also the interesting fact to bear in mind that the brown ware is very liable to spit in the enamel kiln. The spits are particularly prolific where the brown occurs, but not in the blue parts. I cannot go into this spitting now owing to the short time at my disposal, but an elaborate study on the subject will be found in the TRANSACTIONS.

Crazing and Blistering.

Attention might also be directed to the crazing of the glaze in the region virtually coincident with that where the blue china develops. This is illustrated by Fig. 7, which again shows that the region for a satisfactory body is very restricted, being bounded one side by the zone of crazing, and on the other by a zone of blistering or bending.

In conclusion, I should like to direct attention to the blistering. Obviously a vapour or gas is being developed in the interior of the body, and the vitrification of the body hinders the egress of the gas, so that the gas is developed faster than it can escape, and bubbles are blown with the body. As you know too well, the body is quite soft in the biscuit oven; even in the glost oven the body is fairly soft. This dish on exhibition was lying about some years in the biscuit state, and it slowly absorbed moisture from the air. The body is so vitreous that the moisture can penetrate to the interior only with extreme slowness. Between 1 and 2 per cent. is absorbed in approximately two years. The ware was glazed, and subsequently

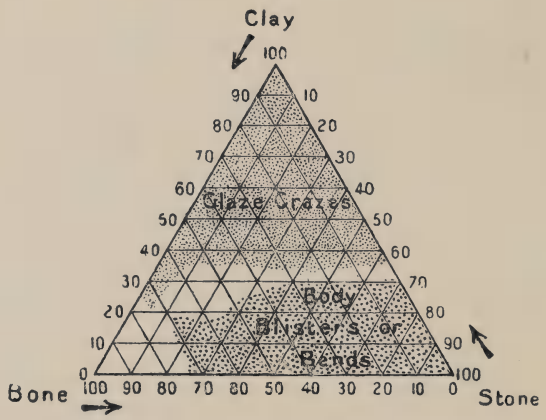


Fig. 7. Bone China Body Triangle, showing zones of blistering and crazing.

fired in the glost oven; the moisture must have vaporized to steam, and the moisture which required months to enter the body could not escape in a few hours. The steam therefore got up an internal pressure and something had to give way. Sometimes the body fractures, but in the present case the body was soft enough to enable the compressed steam to commence blowing bubbles. Examples of both are on the table.

You may retort that the decomposition of the phosphate, as the proportion of stone increases, makes it appear as if the stone favours the decomposition of the bone-ash. I think the facts mean that alumina and iron oxide facilitate the decomposition of the bone, but they fix the phosphate before it has time to blister; the alkalies do the same. I believe there are two distinct actions. The alkalies also get to work vitrifying the body as I have already described, but the free quartz in

stone at the higher temperature acts as an acid and decomposes the phosphate, the bone or alumina phosphate. There is plenty of evidence of the marked action of free silica on phosphates when the temperature of the biscuit oven begins to get high—for instance, "ruckling" and the "greasiness" of bodies in contact with bedding flint, etc. There is, however, room for differences of opinion in the interpretation of the facts available as to the way the stone and clay react with the bone. As soon as we are satisfied that differences of opinion are real it is obviously time to stop arguing, and return to the work-bench for more information.

I have said nothing about the introduction of ball clay, frit, ground earthenware pitchers or of felspar into the body. Similarly also other things may be added rather as mascots, so to speak, than for any utilitarian purpose.

The cause and cure of blue china, and of brown and blistered ware, and of several attendant evils are now so clearly demonstrated, that it would seem to be culpable negligence when the faults appear. Sad experience, however, has taught us that we can expect the biggest falls when we are most elated. We always have the uncomfortable feeling that something has been overlooked. Obviously the right course is to take all the precautions which to the best of our knowledge ought to be taken, and, with C. Piccolpassi, a celebrated potter of the 16th century, trust that all will be well.

XXXIII.—Note on the Borates of Lead.

Communications from the Clay and Pottery Laboratory, Stoke-on-Trent.—No. 92.

By H. V. Thompson, M.A.

On account of the probable formation of lead borates in the fritting process Dr. Mellor suggested that it might be of interest to investigate the identity of the four borates which it is asserted lead forms. (Abegg, *Handbuch der Anorganische Chemie*, Vol. III, Pt. ii, 1909.)

Details of these borates are appended, *viz.*:—

1. Metaborate, $Pb(BO_2)_2 H_2O$. A white precipitate from cold concentrated solutions of lead nitrate and borax; slightly soluble in water, more readily soluble in dilute nitric and acetic acids. The hydrolytic products given by treating this substance with water are not compounds but mixtures with more or less basic salt content. The type has not yet been determined. (Rose, *Pogg. Ann.*, **29**, 455, 1833.)

2. Polyborate, $2PbO, 3B_2O_3, 4H_2O$. Obtained by precipitation of a lead salt with borax in excess. (Soubeiran, *Journ. Pharm. Chim.*, **11**, 31, 1825.)

3. $PbO, 2B_2O_3, 4H_2O$. Treat both the preceding salts with boiling boric acid solution in excess.

4. $PbO, 3B_2O_3$. Melt together boric acid with lead carbonate and treat the melt when cold with water to remove excess of boric acid. (Le Chatelier, *Bull. Soc. chim.* (3), **21**, 35, 1899.)

No. 1. Cold saturated solutions of lead nitrate and borax were mixed in equimolecular proportions with the immediate formation of a white precipitate. The precipitate, which settled very slowly, was washed by decantation several times, filtered off on the suction pump, washed well, and dried at 100°—105° C.

Independent specimens, prepared in a similar way, gave on analysis results varying from 65·31 per cent. to 68·18 per cent. PbO.

An experiment was made in which excess of lead nitrate solution was added to the borax solution; the precipitate was granular and settled more rapidly than in the former case. The precipitate was washed as previously, dried at 90°—95° C., and on analysis 0·9972 grams gave 1·0203 grams $PbSO_4$,

equivalent to 75·30 per cent. PbO. A portion of the precipitate was again washed most thoroughly in order to eliminate any traces of lead nitrate which might have been retained by it. The precipitate was dried at 90° C. and analysed, giving 76·60 per cent. PbO.

None of these experiments confirm the existence of a borate with 71·72 per cent. PbO, and from the analytical results it is apparent that the precipitate is of indefinite composition.

No. 2. 45 grams of a saturated solution of lead nitrate containing 15 grams $Pb(NO_3)_2$ were added to 900 c.c. (18 grams $Na_2B_4O_7$) of a cold saturated solution of borax. An immediate precipitation resulted; the precipitate was granular and settled comparatively readily. The beaker and contents were placed on one side for 10 to 12 days—the liquid being decanted off several times and distilled water added. Finally the precipitate was filtered off, washed well on the paper, transferred to a Buchner funnel and washed repeatedly. Analysis of the precipitate dried at 110° C. gave the following figures. *I.* 71·50 per cent. PbO. *II.* 71·58 per cent. PbO.

A second specimen was prepared as above, dried at 85° C., and on analysis gave PbO 71·87 per cent.: B_2O_3 22·56 per cent.: H_2O 5·60 per cent. $Pb(BO_2)_2$ H_2O requires PbO 71·72 per cent.: B_2O_3 22·49 per cent.: H_2O 5·79 per cent., hence this borate is precipitated from solutions of lead salts by concentrated borax solution in excess and not $2PbO.3B_2O_3.4H_2O$.

No. 3. A portion of the above borate was boiled with boric acid solution in excess, the solution filtered and the precipitate, after washing well with hot water, dried at 85° C. Two specimens prepared in this way gave on analysis: *I.* 67·12 per cent. PbO, and *II.* 69·77 per cent. PbO, whereas $PbO.2B_2O_3.4H_2O$ requires 61·28 per cent. PbO, and moreover the discrepancy between the analytical results does not support the formation of any definite chemical compound.

No. 4. Pure lead carbonate was fused with four to five times the calculated quantity of boric acid, and the fusion continued until the melt was limpid. The cake, after cooling, was extracted with water and only the core retained. The core was ground to a fine powder and placed in contact with water for 14 days with frequent decantation and addition of fresh water. The residue was then filtered, dried at 105°—110° C. and again ground finely in an agate mortar. The dry powder was again treated with water to ensure complete removal of excess of boric acid, filtered, washed and dried as above. 0·9168 grams gave 0·6739 grams $PbSO_4$, corresponding to 51·21 per cent. PbO, thus confirming the existence of $PbO.3B_2O_3$, which requires 51·52 per cent. PbO.

XXXIV.—Notes on the Microstructure of Zinc Retorts.

Communications from the Clay and Pottery Laboratory, Stoke-on-Trent.—No. 93.

By Alexander Scott, M.A., D.Sc.

The following notes are based on the examination of thin sections of various parts of a retort which had been used for the distillation of zinc. The outer yellowish grey portion appears under the microscope to consist of sporadic quartz grains set in a matrix which is almost opaque. The quartz grains have undergone alteration round the margins, where they sometimes appear to merge into the matrix, while at other times they are surrounded by a clear aureole of tridymite crystals. The matrix consists of a clear glass in which are set innumerable microlites. Some of the latter appear to be sillimanite, but the majority are hexagonal zinc orthosilicate. Much of the opacity and brown colour of the glass is due to the presence of these minute crystals. As the blue portion is approached the latter increase in number while the amount of tridymite also becomes greater. Small isotropic octahedra of zinc spinel also appear, the amount increasing as the distance from the blue material diminishes.

A microsection of the blue material shows it to be partly crystalline and partly glassy. The original material of the matrix has been completely changed, the alumina having reacted with oxidized zinc to form spinel, while the silica appears partly as tridymite and partly as silicates of zinc and iron. The grog fragments have also been attacked as they generally show a peripheral layer consisting of microlitic glass, surrounding an unaltered opaque core. The quartz grains have been replaced by tridymite, but round the margins there is often a considerable concentration of needles of willemite. There appears to be two types of zinc silicate present. *Willemite*, the orthosilicate, appears as yellowish-green crystals showing definite outlines and having fairly high refractive index and double refraction The small needles and some lath-shaped crystals which have a hexagonal section also appear to be referable to the orthosilicate. The crystals of metasilicate are found in sheaf-like aggregates which when closely packed appear

yellowish, but which are really blue-green in colour. Spherulitic aggregates also occur, and in some cases these seemed to have formed by the devitrification of a glass.

Some sections show, in the innermost part of the retort, a few crystals which are somewhat larger in size than the average crystals of willemite. These are brown in colour and tend to decompose to a red non-pleochroic mineral resembling hæmatite. Although the crystalline form and optical properties suggest fayalite, the double refraction is decidedly lower than is usually the case with the latter, and hence it is probable that part of the iron is replaced by zinc.[1] The spinel crystals vary in colour from a deep blue to a light blue green, and vary considerably in size, the larger, of course, showing the more intense colour. In their general characteristics, they are identical with the natural mineral, *gahnite* ($ZnAl_2O_4$). The matrix in which these crystals occur is a clear, apparently colourless glass which occasionally shows signs of devitrification.

Although spinel[2] has long been known as one of the chief constituents of used zinc retorts, the information concerning the occurrence of the silicates is more meagre. The latter have been observed by Stelzner[3] and others in retorts, while the presence of willemite has been recorded in the residues left after the distillation of the zinc and in slags. Zinc silicates have also been identified amongst the constituents of certain crystalline glazes.[4] Several syntheses[5] of both ortho- and meta-silicates are on record, but the evidence regarding the latter is somewhat unsatisfactory. The orthosilicate occurs naturally as the mineral willemite and sufficient data concerning the optical properties are available for the ready identification of the crystals. In the retorts under examination, it was the predominant silicate, and in the inner portions was exceeded in amount only by the tridymite and spinel.

The occurrence of fayalite is interesting. Although the relations between zinc and ferrous orthosilicates have not been systematically investigated, it is probably that they are at least partially isomorphous. Some natural fayalites contain as much as five per cent. of zinc oxide, while the rare mineral, *stirlingite*,

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1 Cf. P. Gaubert, *Bull. Soc. franç. Min.*, **30**, 104, 1907.

2 Cf. J. A. Audley, TRANS. **18**, 43, 1919.

3 W. M. Hutchings, *Geol. Mag.*, **7**, 31, 1890. H. Schulze and A. W. Stelzner, *Neues. Jahrb. Min.*, **1**, 120, 1881. P Groth, *Min. Samm.*, 203, 1878. J. H. L. Vogt, *Die Silikatschmelzlösungen*, Christiania, 46, 48, 78, 1903; *Mineralbildung in Schmelzmassen*, Christiania, 33, 199, 202, 207, 1892. Iles, *School Min. Quart.*, **19**, 197, 1898.

4 J. W. Mellor, TRANS. **4**, 49, 1905. K. Endell, *Sprech.*, **44**, 1, 1911; *Neues. Jahrb. Min.* **2**, 142, 1913.

5 H. St. C. Deville, *Compt. rend.*, **52**, 1304, 1861. G. A. Daubrée, *ibid.*, **39**, 135, 1854. A. Gorgeu, *ibid.*, **104**, 120, 1887. G. Stein, *Zeit. anorg. Chem.*, **55**, 159, 1907. O. Mulert, *ibid.*, **75**, 198, 1912. H. van Klooster, *ibid.*, **69**, 132, 1910. K. Endell, *Zeit. angew Chem.*, **26**, 582, 1913.

has about ten per cent. Stelzner[6] has described the occurrence, amongst some furnace residues, of homogeneous orthorhombic crystals with the composition $4Fe_2SiO_4.Zn_2SiO_4$, and containing eighteen per cent. of zinc oxide, and it is very probable that the material observed in the present instance is a similar isomorphous mixture of the two orthosilicates.

The crystals which have been identified as the metasilicate differ from willemite in habit; their outlines are not so sharp and they invariably occur in radial aggregates. They are probably biaxial and have straight extinction and high double refraction, thus agreeing qualitatively with the material described by van Klooster. The fact that their occurrence is rare and apparently confined to a few centres suggests that their formation requires special conditions, while the abundance of the orthosilicate in the presence of so much free silica, indicates that, with the conditions under which the retort is during use, the metasilicate is not particularly stable.

In order to examine the effect of zinc compounds on silica at high temperatures a mixture of zinc oxide and iron pyrites was allowed to impinge on a silica brick at a temperature of 1,400° C., the experiment being carried out in the manner described by Mellor and Emery.[7] A thin section of the brick after treatment shows that the dust had penetrated the brick, this penetration being confined to the matrix and the rock-fragments being practically unaltered. The quartz of the matrix was completely altered and largely recrystallized as tridymite in lath- and wedge-shaped crystals. The iron pyrites had been oxidised to magnetite and the zinc oxide had reacted to form silicate. The latter occurred in prismatic crystals with well-defined cleavage, straight extinction, high refractive index and moderate double refraction. The interference colours indicated a value of ·015 for the last, which agrees approximately with the figure obtained by Gaubert for willemite containing about 10 per cent. iron oxide. Since the other properties agree with those of willemite, the mineral present is almost certainly a mixture of the orthosilicates of iron and zinc. The presence, in parts of the brick, of ophitic aggregates of willemite and magnetite in the midst of abundant tridymite suggests that even in the presence of zinc silicate, magnetite does not react to any great extent with free silica.

A brick which had been attacked by Cowper's stove dust, containing 15 per cent. zinc oxide and 27 per cent. iron oxide, showed only fayalite, tridymite and brown glass in the matrix,

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[6] A. W. Stelzner, *Neues Jahrb. Min.*, **1**, 170, 1882.

[7] J. W. Mellor and W. Emery, TRANS. **18**, 230, 1919.

the two latter predominating. The amount of fayalite was very small, and most of the iron and zinc oxides were in the brown glass. It seems probable that under the conditions obtaining in zinc retorts, zinc oxide reacts with the free silica of the retort to form the orthosilicate and not, as might be expected, the metasilicate. It is possible that under certain conditions the latter, like ferrous metasilicate, does not separate in a free form but breaks up to give the orthosilicate and free silica. In each of the cases described above, the silica was in excess of that required to form the metasilicate, yet the final zinc salt was willemite. The results obtained above are in favour of Vogt's view that the orthosilicates of zinc and iron form two series of mixed crystals, one rich in zinc and crystallizing in the hexagonal system (willemite) and the other, rich in iron and forming orthorhombic crystals (fayalite). As the location, in the retort, of the parts examined is not known, it is not proposed to enter into a discussion of the bearing of the results on the process of zinc distillation.

XXXV.—The Standardization of Tests for Refractory Materials (Part III.)

Report of the Committee, consisting of Prof. J. W. Cobb, B.Sc., Dr. H. G. Colman, Major C. W. Thomas, Messrs. F. H. Brooke, W. J. Brooke, A. Cliff, J. Allen Howe, Cosmo Johns, B. Moore, D. J. Pinkerton, W. J. Rees, Sir W. J. Jones, and Dr. J. W. MELLOR, Hon. Sec.

XIV.—The Penetrative Action of Slags.

THE penetrative action of slags on fireclays and firebricks can be conveniently examined in three ways. In the first place the clay mixture can be pressed into hollow blocks of the dimensions indicated in Fig. 1: Outside $2\frac{1}{4}$ in. square, $1\frac{1}{2}$ in. deep. Inside $1\frac{3}{4}$ in. square, $\frac{3}{4}$ in. deep. The blocks are fired to the desired temperature, say cone 10.

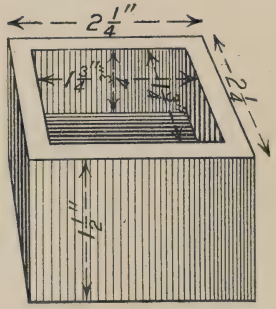

Fig. 1.

When cold, the desired slag is placed in the receptacle and the whole is then again fired to the desired temperature for the desired period of time, say four hours. When cold the block can be sawn across as indicated in Fig. 2. The penetrative and corrosive action of the slag on the mixture will then appear.

This method does not enable the action of slags to be determined on firebricks because of the artificial treatment involved in making the blocks. In the second method a hole, say 2 in. diameter and $\frac{1}{2}$ in. deep, is bored in the brick and

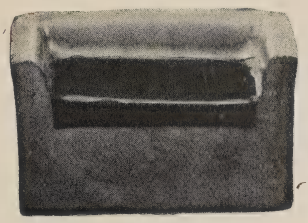

Fig. 2.

filled with slag. The whole is then fired and treated as in the previous case. Neither of these methods gives any idea of the peculiar resistance which the surface skin of a brick offers to the penetrative action of a slag. This is best examined by Nesbit and Bell's method.[1] A ring of stoneware is cemented to a firebrick, as illustrated in Fig. 3, by means of a thin film of fine grog and silicate of soda mixture.

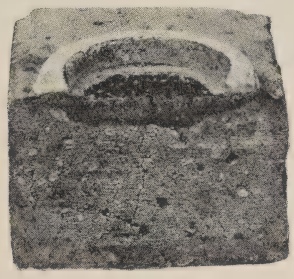

Fig. 3.

The receptacle so formed is filled with slag and the whole is treated as before. The penetrative action of the slag can then be examined by sawing the brick across as in Fig. 3. This plan is of general application to firebricks and gives good results.

1 Nesbit and Bell, *Proc. Amer. Soc. Test. Mat.*, **18**, 345, 1918.

Mr. G. ADAMS.

IT is with deep regret that we have to record the death, since the last number of the TRANSACTIONS was published, of Mr. George Adams, a highly respected member of the Society, who became associated with it in its earliest years, and who later served for many years with ability and enthusiasm on the Council.

The death of Mr. Adams occurred somewhat suddenly at his residence, "Cloverley," King's Avenue, Wolstanton, on January 2nd, 1919, from pneumonia, contracted almost on the eve of Christmas. It will not be news to many of the members of the Society that the late Mr. Adams was, for many years, the ceramic chemist of Messrs. Josiah Wedgwood & Sons, Ltd., of Etruria, for whom he accomplished much valuable research work, leading up to many of their more recent triumphs. Although a man of technical ability, who had amassed a fund of valuable knowledge and experience of high-class ceramics—the result of a lifelong application

to a remarkable industry—the deceased always impressed one by his quiet humility. Whilst naturally undemonstrative, he was free in his manner, and always willing to discuss with others similarly-minded the burning problems of the intensely interesting calling which it was his privilege to follow.

It can safely be said that in a quiet way he accomplished great things for the historic firm for whom he worked in his later years, and that also in his quiet talks in the meetings of The Ceramic Society he was the means of helping to throw a ray of light on many a dark subject.

The late Mr. Adams was thoroughly respected by all, and his helpful presence will be sadly missed by those members of the Society who knew him intimately. At the January meeting the announcement of his death came quite as a sensation, and the vote of sympathy, proposed by the Chairman and seconded by A. G. Richardson, who knew him well, was accorded in impressive silence, the members standing, to signify their unreserved approval of all the tributes that were spontaneously and justifiably paid to his memory.

H. T.

PROCEEDINGS

1918-19.

Proceedings.—Session 1918-19.

General Meeting held in the Central Technical Schools, Stoke-on-Trent, on Saturday, 12th October, 1918. The President, Mr. R. L. JOHNSON, presided over a meeting of 53. Dr. A. Scott was elected Hon. Librarian in succession to Mr. P. S. Devereux. A vote of sympathy with the relatives of the following late members was passed: Lieut. S. A. Grimwade, killed in a flying accident, and Messrs. F. Wiltshaw and E. G. Jones. Dr. C. H. Desch read a paper entitled "The Setting of Plaster." A vote of thanks to the lecturer was proposed by Mr. D. F. W. Bishop, seconded by Mr. J. G. Roberts and carried unanimously. A discussion followed in which Dr. Mellor, Dr. A. Scott and Messrs. A. Leese and W. Emery took part. Proposals were received on behalf of: (1) Collective Members, Messrs. The Shelton Iron & Steel Co., Messrs. Bolckow, Vaughan & Co.; (2) Individual Members, Messrs. P. Dressler, Wm. M. Anderson, C. A. Webb, F. Mansfield, F. W. Higgins, D. M. Francey, A. Bigot, D.Sc., C. Billington, L. E. Barringer, C. H. Hardy, H. G. Schurecht, G. Cleland, W. J. Elsworth, J. W. Bowers, T. H. Rogers, E. D. Nicholson, D. W. Ross, W. J. Tatler, G. A. Keeling, Robt. Blair and T. H. Lloyd.

An Open Meeting was held in the Central Technical Schools, Stoke-on-Trent, on Thursday, 14th November, 1918. The chair was occupied by the PRESIDENT, the attendance was about 100 and included several ladies. An address was given by Sir Henry Cunynghame, who subsequently opened the Solon Library. A vote of thanks to the speaker was moved by Mr. F. B. Johnstone, seconded by Mr. B. Moore, supported by Dr. J. W. Mellor, and carried unanimously.

General Meeting held in the Central Technical Schools, Stoke-on-Trent, on Saturday, 14th December, 1918. Mr. J. A. CALCOTT presided over a meeting of 30 members, and welcomed Mr. Herford Hope, a member of the Society who was serving with the U.S. Navy. A vote of sympathy with the relatives of the late Mr. H. Wicks was passed. The following new members were nominated: (1) Collective Members, Messrs. Bourne & Leigh, The Blythe Colour Works, John Morton & Co., Swinnerton & Co.; (2) Individual Members, Messrs. W. Temple Gardner, F.I.C., R. Thomas, N. H.

Weatherley, Lieut. J. R. Malkin, H. L. W. Kent, G. N. Neill, D. le l'Herman, E. R. Metcalf, W. Negus, H. W. Gipp, E Walker, M.Sc., L. Meredith, H. J. Toogood, W. F. Sutherland, D. Sillars, and W. R. Bates. Mr. M. P. Ferneyhough read a paper entitled "Apparatus for the Charging and Drawing of Ovens." A vote of thanks to the lecturer was proposed by Mr. T. G. Simpson, seconded by Mr. H. Hope, and carried unanimously. The following gentlemen took part in the discussion:—Messrs. A. Leese, W. E. Goodwin, G. Reynolds, J. Johnson, W. Lindley, J. Williamson, and H. L. Jones.

A Meeting was held in the Central Technical Schools, Stoke-on-Trent, on Thursday, 9th January, 1919, in co-operation with the Pottery Manufacturers' Association. The PRESIDENT presided over a meeting of 80. Proposals for membership were taken on behalf of Messrs. Peter Bailey & Sons, The Director General, Cie. des Forges et Acièries de la Marine et d'Homecourt, Messrs. P. G. W. Bayley, Johnson Pearson, and F. Graves Clark. The Chairman announced the unavoidable absence of Dr. A. Bigot, whose paper, entitled "Ovens and Kilns with High Thermal Efficiency," was read by Mr. D. F. W. Bishop. A vote of thanks to the author and reader of the paper was proposed by Mr. J. Burton, seconded by Mr. F. Turner, and carried unanimously. In the long discussion which followed, Dr. Mellor, Messrs. B. Moore, C. Bailey, A. Fielding, W. J. Rees, B. J. Allen, H. J. Plant, J. W. Hartley, J. H. Marlow, J. C. Bailey, and J. Williamson took part. The Chairman proposed a vote of congratulation to Sir Wm. Jones, last year's President, on his Knighthood. The motion was carried unanimously, amidst applause.

A Meeting was held in the Central Technical Schools, Stoke-on-Trent, on Saturday, 18th January, 1919. The PRESIDENT presided over a meeting of 25. A vote of condolence was passed with the relatives of the late Mr. G. Adams, member of the Council. Messrs. G. H. Walton and E. M. Myers were proposed for membership. Mr. W. Emery read a paper entitled "The Standardization of Chemical Stoneware," written by Mr. Harald Nielsen. A vote of thanks to Mr. Nielsen was proposed by Mr. B. J. Allen, seconded by Mr. A. Leese, and carried unanimously. Communicated contributions to the discussion, sent by Prof. J. W. Hinchley, Mr. G. A. Hodson and Mr. M. Barrett were read. Messrs. D. F. W. Bishop, C. E. Ramsden, A. Heath, B. J. Allen, A. Leese, and Dr. Scott took part in the verbal discussion.

ADDRESS BY SIR HENRY CUNYNGHAME ON THE OCCASION OF THE OPENING OF THE SOLON LIBRARY.

THE CHAIRMAN (Mr. R. Lewis Johnson—President of The Ceramic Society), in opening the meeting, said:—I feel that this is a very auspicious occasion, being the first meeting of The Ceramic Society and the Art Section of The Ceramic Society together. We are here for the purpose of opening the Solon Library, which, you are all well aware, is an exceedingly valuable collection. You will probably be interested to learn how we came to acquire the library. Towards the end of 1915 Sir Graham Balfour was in communication with the Carnegie United Kingdom Trustees about a grant for school libraries in the county, when he learned that they would possibly be willing to find money for establishing an adequate National Library in connection with the pottery industry. Sir Graham privately consulted Dr. Mellor, who told him that the Solon Library had not yet been dispersed, and that in his opinion it was the finest library of the kind in the world and should if possible be secured for Stoke. Sir Graham therefore communicated accordingly with the Secretary of the Trustees, Mr. A. L. Hetherington, and as the result of these negotiations was able to inform Mr. Philip Elliott, the Chairman of the Governors of the Central School of Science and Technology, that an application from him would be favourably considered. It was obviously necessary to keep secret the source from which the money would be forthcoming, and Dr. Mellor conducted the negotiations with much astuteness and discretion. In the end Mr. Elliott was able to announce to the Governors on 17th February, 1916 that, subject to the contents of the library being rendered accessible to any earnest student, the Trustees were willing to find the purchase money of £2,000.

The library, as you are aware, has been duly housed and catalogued, and is receiving suitable additions from time to time as occasions arise.

The Carnegie United Kingdom Trustees are a body established by Mr. Andrew Carnegie in 1913, to whom he handed over ten million dollars, of which the income was to be spent for the improvement of the well-being of the masses of the people of Great Britain and Ireland. Mr. Carnegie's well-known enthusiasm for libraries, which is recited in the Trust Deed, doubtless rendered the Trustees favourably disposed to expenditure on such an object as the Solon Library. There is no doubt that in the near future there will be libraries established for special industries in this country, but, so far as I

am aware, the Ceramic Library now in the Pottery School at Stoke is—apart from the libraries of such professional associations as the Institute of British Architects or the Institute of Civil Engineers—the first large institution of this kind in this country.

I have a very pleasant duty to perform, and that is the introduction of our worthy and honourable friend Sir Henry Cunynghame. I have much pleasure in introducing Sir Henry Cunynghame.

Sir Henry Cunynghame:—I propose to preface the opening of this library by saying a few words upon industrial decorative art and what can be done to improve it.

The great difference between art and science is, that science is concerned with intellectual truth and can be clearly defined. Thus the study of chemistry is the study of a positive science. There can be no two opinions upon matters of facts in chemistry. But art depends upon the emotions, and upon matters of art no two opinions can ever exactly coincide. In vain we try and discover rules by which art can be tested, and good and bad art determined. All such rules fail. The use of stamped ornament is condemned by some critics, but we are immediately confronted in Greek coins with the most beautiful art production. Imitation of materials is condemned by others, but the use of gold was at first entirely imitative. Some contend that each industrial work of art should be entirely hand-made, but we at once feel that this rule would put art entirely out of reach for all the poorer classes. The truth seems to be that works of art derive their charm partly from laws of form and colour too subtle to be formulated, and partly to historical, national and personal associations which differ for different men. From this it seems to follow that the best way to discover what is good art is not to theorise, but to try and find out what kinds of art give the most permanent and elevating pleasure. Just as it is of no use for poetry or literature to talk habitually over the heads of the people, so we shall never persuade anyone to purchase what he does not desire to possess. And in art "laws" are usually rather a hindrance than a help. For example, in the art of musical composition certain empirical laws have been in force for over 100 years, as for instance that one may not have two consecutive fifths, and that the cadences or closing passages of composition should follow certain rules. These rules are now

being abandoned. Not one of them but is now broken with success. A past generation applauded the rule in decoration, that only complimentary colours should be juxtaposed, so that a combination of blue and green was forbidden. But Nature revels in blue and every sort of shade of green. It is impossible to look through any book of Chinese designs without seeing blue and the brightest green most successfully united. Indeed the conclusion must be admitted that there are no two colours that cannot be successfully put together provided proper measures are taken to do so.

The arts of design are, however, not without some general principles. Of these perhaps the first and most important is that the design should be adapted to the material. One would not carry out a design intended for wrought iron, which can be drawn out into leaves and tendrils, in cast iron, whose characteristic is solidity and resistance to pressure. The making of lace in pottery is permissible occasionally as an exhibition of craft and skill, but would be intolerable as a general rule.

So again the art must be appropriate to the morals, manners and religion of the people. A representation of a bleeding heart would be simply disgusting unless it were associated, as it so often has been in religious art, with the sorrows of the Virgin Mary, or in heraldry with the death of Bruce.

And lastly, ornament should be coherent. Most good ornament has a regular historical development. Thus the woven mats of the South Sea islanders, which at first look to us like mere complicated chess board patterns, turn out upon examination to be quaint lizards, birds and snakes. All our ornament can be shown to have its roots in very early times. Even the buttons on our coats related back to the time when swords were worn.

Thus the violent attempts to unite ornaments of a diverse historical character offend us just as if the painter were to put the head of a Chinese mandarin on the body of an English field marshal, or the head of a cat upon the body of a horse. A large portion of our modern art offends from a breach of this rule—a breach which is instinctively felt even by those who cannot wholly analyse the cause of their feelings.

Sometimes those who come to industrial centres lecture their hearers on the wickedness of working for money. Of course the love of money may be abused like the love of fame, or the love of power or the love of lecturing other people.

But if an industry is to prosper, those engaged in it must satisfy their patrons: they must live.

If I were asked what would be the greatest glory for the Potteries district, I should answer, not the production of the most beautiful china or earthenware, but the production of a number of happy and virtuous homes with contented men and women and healthy children. To produce this is more important than to produce the finest dishes that ever adorned the dinner tables of princes and kings.

The potter then, must live, and to live he must find a ready sale for his wares; and to find a ready sale for his wares he must produce goods which people like and will pay for, and, as a rule, the more they can be got to pay the better for the potter, provided always that the potter's wife knows how wisely to spend his gains. In order to find out what the people like it is of no use to shut oneself up in one's room and read the works of Ruskin. A costermonger with a crockery barrow in the New Cut knows more of what will give pleasure than Ruskin. I often wish that some earnest attempts were made to find out what the poor do like, and then to improve it, rather than to discuss what they ought to like. The latter plan savours so much of the scientific methods of the schoolmen who theorised upon ideals, instead of experimenting.

In the discovery of what pottery ought to be, artists and even art schoolmasters are not always the best guides. By his very powers an artist is apt to be limited. His success depends on his specialization to a particular style. This specialization is the source of his strength, but it largely disqualifies him from appreciating the work of others. What the pickaxe gains in incisive power it loses in breadth.

The difficulty of guiding taste in such work as pottery arises in no small degree from the fact that only a limited number of people buy, or ever will buy articles because they are beautiful, or because they themselves think that they are beautiful. If people would only buy what they themselves really liked the foundations of improved taste would be laid; but they do not. For example, what guides a girl in the selection of a hat. First, you will say, the utility of it. It should shade her eyes from the sun. Is this what she chooses it for? If so, why do hats vary in shape from umbrellas to flower-pots? Is it because it suits her complexion? If so, why does she acclaim a hat one year and in six months declare it intolerable?

The truth is that most works of ordinary art manufacture are bought simply for the sake of display. With what object does a rich amateur make "a collection" say, of pictures? Talk to him, you will see that he cares but little for masters of whose works he has not a specimen. He too often collects

for the sake of display. And if we will be honest we shall see that our public buildings are built mostly for the sake of outrivalling a neighbouring town. If a church committee buys an organ, they are deeply mortified if they find that a chapel committee has purchased an organ for the same money but with 100 more pipes in than the church organ. They do not listen to the tone, they are too busy considering how much the case must have cost. When a present is given how often we choose something because it looks as if it must have been expensive. History affords numerous examples of the degradation of art by the love of magnificence being changed into a love of ostentation.

So long as this desire for display exists (and when will it end?) things will be bought rather with an eye to satisfying the general taste of one's friends than one's own. Hence, if we are to improve the arts, we need above all to improve the general standard of taste among buyers. Tastes usually go from above downwards. Peers build houses to imitate palaces; country gentlemen build houses to imitate peers; people of small fortune build houses to imitate the gentry, until we come down to the working classes, who buy a rosewood piano that occupies most of the parlour. The desire of display is so bound up with our social life that, if torn up, even the best and most legitimate desires for progress might be torn up with it.

In considering how the general standard of taste is to be improved it must be remembered that, in a large population, only one person in twenty, or shall we say fifty, takes the slightest trouble to think for himself upon any subject whatever. We all follow our leaders like sheep, in politics, in religion, in morals and in art.

This somewhat simplifies the problem, for if you can educate your leaders your work is done.

This is not altogether impossible, though the process must be a slow one. It will not be done by dogmatism. The improvement in taste will rather partake of the character of a slow social evolution.

I propose to consider some of the schemes which have been suggested for the improvement of art.

In the first place there are our schools of art.

We have now had in operation for about half a century the schools which were initiated to a great extent by the efforts of the Prince Consort. The efforts made by him were chiefly directed to the popularising of a knowledge of elementary drawing and colouring, and there can be no doubt that a very great and useful work has been performed by them. Considered as grammar schools of art their influence

on industry has been enormous, and the great improvement in popular art that has taken place in the country in the last 30 years is largely due to their influence. But it is sometimes forgotten that if you can teach the grammar of art you cannot teach taste. It is as impossible as it is to teach poetry or musical composition. As a preparation for poetry writing you can teach grammar and literature, or as a preparation for musical composition you can teach harmony, but you cannot make a man a poet or composer. Any attempt to do so only produces a pedant instead of an artist.

Hence then a school of art designed for the improvement of industry should aim, not at producing works on art to be admired at great displays, but should aim at the humbler work of teaching drawing, and of giving instructions in the characteristics of the schools of art that have in the past done the best work. The students should be made familiar with the Greek style, Gothic work, Renaissance design, French design, German and Italian and Spanish design, so that they would not spoil their work by a senseless mingling of incoherent ornament. They would be able to recognise designs when they saw them and not mistake Chinese for Japanese.

For in design it is a great mistake to argue that some styles of art are bad and some are good. All are good if the art is good. Good Louis XV is very beautiful, and even in Victorian art some very good examples can be found. Let then the aim of our art schools be catholicity, good sense and modesty, seeking to instil solid knowledge in the students rather than a premature exercise of the inventive powers. How absurd would be the conduct of a professor of engineering who should begin his teaching by setting the pupils to make inventions. The success of our science teaching lies in the fact that its instruction is solid and commences by dealing with facts rather than opinions.

I may also add that an effective school for the improvement of industry must be in close contact with, and largely controlled by, those engaged in that industry. The master potters, designers, and workmen of a district know what they want to learn, and when what they want is offered them they usually seize it with avidity; but schools conducted according to ideas from outside usually fail.

It is on these principles that those engineering and mining schools have been founded in various industrial centres in Great Britain which are now becoming such brilliant successes. They are financed and governed without outside interference by those engaged in the industries which they are designed to promote.

I now pass to other methods. There has been recently established by the Board of Trade and the Royal Society of Arts a British Institute of Industrial Art, whose object is to be to raise and maintain the standard of design and workmanship, and to stimulate the demand for works of excellence.

One of the means proposed is to have a permanent exhibition in London to which such modern British works of craft and manufacture shall be admitted, as shall be approved by selection committees, and some of the exhibits shall be purchased for the National Museums. A selling agency is to be attached to it. The addition to museums of modern work ought to be very valuable, especially in the provinces; but I think we must not expect too much from the general scheme. In the first place it must be remembered that in all our principal towns there are shops which are open always, and the managers of which spend most of their time in rendering as fit as possible the display of ornamental goods of every description. To set up in the chief towns large rival shops under Government officials, for the exhibition and sale of goods, seems questionable policy. If they succeed largely it can only be by the discouragement of the general trader, and I greatly doubt whether manufacturers will prefer to send their goods there and in any way to throw over the retail shops to which they have been in the habit of sending their goods. I doubt also whether our leading manufacturers would present their work every year for criticism and rejection by a Government board of examiners, or expose themselves to the possibility of a rebuff by being refused a place in the exhibition on the ground that their work was bad art.

In the next place, I doubt greatly whether the public would be prepared to be led in taste by a Government department. I admit at once that an exhibition of pure drugs, or chemicals, or pure beer, or unadulterated jam (all of which are blessings not completely enjoyed at present) would result in substantial improvement in manufacture, but the reason is that the purity of a thing is not a question of opinion, but simply one of fact. But what are we to say of a Government committee of taste? Tastes vary in the most capricious way. The world has seen the noblest classical work of antiquity destroyed and even burned to make lime for building Gothic cathedrals. It has seen the walls of those very Gothic cathedrals hacked about to make room for modern classical design, and classical ornament again removed to make room for revivals of Byzantine.

Let us consider what the effect would be of the yearly publication of a Government poetry book to which only those

poems were admitted which satisfied the taste of a Government department; or to take an instance more connected with industry, will the new institute presume to establish an exhibition of ladies' dresses, to which only those hats and garments shall be admitted which satisfy the Government committee of selection? When we test the scheme by instances like these we see its limitations, but we are apt to forget that in trades like the pottery trade precisely similar difficulties arise.

I confess I believe that art is best when freed from the trammels of Government supervision; it must grow naturally, and not be placed too much under the hands of a gardener. Those who are engaged in the pottery trade are often treated by those who come to lecture to them as though they were barbarians with no knowledge of art; but people who have a more intimate knowledge of the trade will recognise that the potters have a far greater knowledge of art as applied to their industry than they are often credited with. Their difficulty is not nearly so much to produce good work as to get the public to buy it. Moreover, the situation is complicated by the fact that the self-constituted critics of pottery are all at variance with one another. No two people are agreed as to the choice of such a simple article as a tea cup. I would warrant that if 50 tea cups were put in a room, and each member of a Government committee of taste were sent in alone to choose the one he thought best, that almost every member would choose a different tea cup and that almost every member would condemn the tea cups which had been selected by the others. I should like to see the experiment tried in practice. If that is so, what becomes of your selection? The very cup that offends us to-day by its originality may become the prize-winner of the future. What would become of the deliberations of a committee of judges of painting which contained a pre-Raphaelite, an admirer of Rembrandt, an admirer of Reynolds, an impressionist, a realist, a cubist and a post-impressionist. A committee so composed could only end either by passing nothing or else arranging to pass everything. In either case their deliberations would be useless. The one thing they would never do would be to agree on any one picture.

In pottery ware, unfortunately, there is a steady demand in the cheaper articles for articles of which the taste is bad. Forbid them to be made and the only result will be that they will come over in still greater numbers from Germany. No effect will have been produced except to take away the livelihood of a number of potters.

As I do not wish to adopt the position of an unfriendly critic of those who, instead of talking, are earnestly trying to cope with a most difficult subject, I would venture two suggestions for public action.

Those who examine the teaching given by our leading universities must be astonished at the neglect of art. Thus in Oxford University, though there are professors and lecturers of the university, not to speak of the large body of teachers connected with the various colleges, there are only two for art, a Slade professor of art and a Ruskin teacher of drawing, whose names in the University calendar rather characteristically are put at the bottom of a list of 138 professors and teachers. Every sort of study is there, Chinese, Japanese, Hindoo theology, epigraphy, but not one professor or even teacher of the great art of architecture or of design, arts which throw so much light on the study of literature which is the glory of Oxford University.

It is surprising that the twelve or fifteen thousand clergy to whom is committed the care of the most interesting collection of parish churches in the world, are as a rule totally ignorant of the elements of architecture. Is it surprising that the committees of our local councils, who select designs for our town halls, would be for the most part quite unable to recognise a Palladian building if they saw it, or to distinguish a Lombardic design from a Gothic. Do they adopt the principle of the marquis in Molière's play, that "Un gentilhomme scait tout sans apprendre"? I am glad to learn that at last Oxford is waking up, and that a committee is about to report upon this important subject. Though taste cannot be taught, subjects such as architecture can be taught if they be treated as being in reality languages, subject to the laws of evolution and exhibiting resemblance such as are found in kindred tongues. One cannot make every man an architect or a poet, but every one can be educated to understand and appreciate architecture and poetry, just as every one can learn French.

Again, the art of painting exhibits a steady progression from Byzantine times to the present day, and the pottery of every age bears a close relation not only to the architecture and painting of the period, but to its literature. How usefully these elegant arts could be made to illustrate and to relieve the tedium of severer studies.

The art of pottery lends itself in a remarkable degree to historical treatment. We possess, fortunately, a large number of splendid works on various schools. To look through the illustrated pages of works on Chinese porcelain, showing the

rise of the art from early periods to its fall at the Taiping rebellion, is in itself an art education.

In Staffordshire the rise of a local and national art has often been largely checked by the icy breath of criticism, but still a continuity in it can be traced, and its development is worth study. A modern potter ought to be ashamed not to have an acquaintance with the history of slip ware, of the Toft school, of the Elers, the Wedgwoods, Spode, and the early Victorian potters.

Many visits to Stoke at intervals during the last 20 years have drawn my attention to a defect in our laws, which is more responsible for deficiencies in art than might at first appear. I mean the very imperfect manner in which art design is protected by the laws. And here I speak as one who at one time practised as a patent lawyer.

One of the reasons why it is now so difficult to obtain and remunerate designers as one would desire to see them employed and remunerated, is, that anyone who spends money on the foundation of good design usually finds that he incurs pecuniary loss by his efforts. For the present law for the protection of designs is very imperfect. It does not provide sufficiently for the prohibition of colourable imitations of those which, though they may differ a little from the original, only do so by some very insignificant difference. Examples of this are found everywhere. Take this cup for an instance. This little cup was bought by Lady Cunynghame and at a distance appears a beautiful thing. What it really is, is a cheap German imitation of Minton. It is a scandal that it should have been admitted into England. Again, there is another thing. At this moment I have in my pocket a circular announcing the change of name of a German to an English name. He is a consulting chemist. The name he has taken is that of a well-known English consulting chemist. I wonder why he has changed his name? I say that names of firms who are producing pottery should be impossible to mistake their true nationality or identity.

Again, a great defect in our law for the protection of design is that there is no provision for granting protection from the outset. Everyone is left to copy at his peril, and perhaps lay the seeds for an expensive law suit, which will only be decided after the season is over and new designs are required.

Moreover, infringement of design is a matter not capable of being determined by merely abstract considerations. How far some object is an infringement of the design of another is to a large extent a matter of opinion, just for example, as is a question of libel. It would therefore seem desirable that

some means could be proposed by which protection for limited periods of designs should be able to be granted by a tribunal upon which trade experts should be represented. The matter is one for the pottery trade whom it chiefly concerns.

I refrain here from going into details, but I think that it is worthy of consideration, whether some action could be taken to secure to the originators of designs protection such as that conceded to the authors of books.

Personally, although I am a free trader, I should be disposed to go further, and to see protected tariffs placed upon certain branches of the pottery industry.

Art trade is naturally a thing of tender growth, it therefore especially needs a little nurture in its early years. The best art has always needed some form of care and patronage, and the production of works of art is not a growth as hardy as the trades of soap making or chemicals. There are several forms of art which are almost non-existent in Great Britain, but which if initiated and fostered for a time by means of protection would grow up hardy industries. Of these pottery is an example, and if the law is to be strengthened in the direction of protected tariff there is no trade which would more repay protection than ceramic ware.

The trade is in need of the application of fresh capital, and the creation of new skilled labourers, and no means would be so calculated to call this labour and capital into existence as a measure of protection which would ensure both to masters and workmen the fruits of their efforts in the development of new branches of this industry. In the long run a well devised scheme of production does not raise prices. The improvement in production by the application of capital, and by the development of a body of skilled artizans, produces an increase in efficiency which enables prices to be lowered by more than they had been raised by the tariff, and which eventually benefits the consumer as well as the producer. This is the reason why in practice protection does not raise the prices of protected manufactured goods so much as merely theoretical considerations might lead us to imagine.

I now pass to the main subject which brings us here this evening.

In 1916 the generosity of Mr. Carnegie enabled the governing body of the Ceramic School to prevent the dispersion of the splendid library which had been collected by Mr. Solon.

I do not propose to retail the events of his life, because they have already been made known by Mr. Hobson in a paper read in this place in 1916. It is sufficient to say that he was born in France in 1835, that in 1870–1 he was driven from

France by the events which followed the brutal aggression of Germany in that year, and by which the progress of the arts was temporarily interrupted. He took refuge in England and came to Stoke, where he married the daughter of the director of Minton's works, with which his life became thenceforth closely associated. Personally, I remember him very well, and have had the pleasure of being shown over his library by him.

He was a familiar figure—a Frenchman—with all the animation and the artistic enthusiasm of his race. Some among the audience were his intimate friends. His books were, so to speak, his pet children. No one can examine his library without being astonished at the completeness of its contents. The most rare and beautiful volumes are here, in binding that are worthy of them. I hold in my hand one of his favourite and most precious volumes, a first edition of the first work of Bernard Palissy.

He was himself an author of excellence and of industry. Here, for example, is a list of all works on pottery known in his day. The compilation of this must have cost severe labour.

Here again are large volumes beautifully illustrated on every branch of art.

As an author he possessed a keen sense of humour. For example, in the book by him which I hold in my hand—itself very rare, for only a few copies were printed—is related the story of the Buccaro pottery, brought from Mexico to Portugal in the 16th and 17th centuries. This earthenware was highly perfumed. So much so, that pounded portions of it were employed in the preparation of sweetmeats. Even the china was sucked and eaten, and a lady brought on a serious indigestion from having rashly consumed a whole cup and saucer at one sitting.

I need, however, not dwell on his life. In the case of great artists, and where we are fortunate enough to possess their works, we may say, "If you want to see their monuments, look around you."

The library possesses a large collection of his designs and drawings, which have been classified and arranged by Miss Bratton, and to which I am now enabled to invite your attention. Some are on these walls, others are in an adjoining room. On looking at them you will ask yourselves whether it is Leighton's work you are looking at, and very often you will be reminded of Raphael. In any case you will say that there are the works of an artist of the first rank, to see whose work will well reward a pilgrimage to Stoke.

I hope that the authorities may see their way to have them exhibited in some permanent and fitting manner.

How sorry we must all feel that Solon died in 1915, aged 80. How would he have rejoiced to live a few years more to have witnessed the punishment of the barbarians who for the second time have plundered his country, and carried off so many works of art and articles of beauty which their degraded minds were unable to originate, and which they at best can only use for the purpose of making cheap and fradulent imitations.

Stoke has not been unmindful of her artists in the past, but of all those who have done a life-work in the Potteries, not the least of the names which will go down to posterity is that of Stoke's adopted son, the Frenchman, Louis Solon.

DISCUSSION.

Mr. T. B. JOHNSTONE (Bristol):—It is with the very greatest pleasure, and with the certainty that you will all heartily agree with me, that I propose a vote of thanks to Sir Henry Cunynghame for his most instructive and entertaining lecture. It is a fortunate accident that brought me to Stoke this evening, and which has enabled me to listen to such a delightful discourse, with its shrewd insight into human nature. My memory goes back almost as far as Sir Henry's, and I well remember the vogue of complementary colours that he referred to. I have a distinct recollection of a dear old aunt of mine who used to come out in most extraordinary colours, and always prided herself on the fact that they were such an excellent contrast. There has undoubtedly been an enormous improvement in taste since those days. When I first went into the pottery trade, now nearly 40 years ago, I was horror-struck with the decorations we were then selling, and I endeavoured to bring about better styles, at any rate more pleasing to myself. But I found it was quite useless, the goods could not be sold; they did not suit our customers. Therefore I had to turn round, and now I am a very good judge of what will please the miners in South Wales.

Sir Henry referred to the part which love of display takes in deciding the purchase of an article, and there is a great deal of truth in this. I am told the miners in South Wales, or rather the miners' wives, have dressers, and on these dressers they display dinner services, and they rival with one another as to the number of these dinner services they have. Mrs. Jones will say: "Mrs. Smith next door has two dinner services, I must have three"; then Mrs. Smith must outdo Mrs. Jones by purchasing four. Then competition comes in as to the

amount of colour, and I am not sure that weight is not also reckoned as a factor. We can only hope to improve the taste of the public by education; it is really a question of education, better housing, and better wages. When these three things are brought about I have no doubt the taste of the public will gradually improve, and then the real artists in this district will come into their own, and find their efforts appreciated as they have not been in the past.

I was very glad to hear Sir Henry say at the close of his lecture that, although he has been a strong free trader, he sees no reason why we should not relax these rules in particular instances if it is to the national advantage. I think the whole nation now has come to the same conclusion. I daresay you have seen the programme of the Coalition Party which has just been put forward, and its recommendation of an anti-dumping law. This will mean that in future there will be no dumping, which will effectually prevent such abominations as Sir Henry Cunynghame has referred to this evening.

I have great pleasure in proposing a hearty vote of thanks to Sir Henry Cunynghame.

Mr. BERNARD MOORE:—It has given me very great pleasure indeed to second the vote of thanks. We have all been very much delighted with the paper that Sir Henry Cunynghame has read, and I only hope that in the future the taste of the industry will take same position in the world that the quality of British ware is doing at the present time.

Dr. J. W. MELLOR:—Mr. Chairman, I have very much pleasure in supporting the vote of thanks which Mr. Johnstone and Mr. Moore have proposed and seconded. I really must express my personal thanks, and the thanks of our Society, to Sir Henry for the willing way in which he has always helped us whenever we have had occasion to ask him.

I think I ought also to take the opportunity of placing on record the fact that many a time Mr. Solon has told me that he would have bequeathed the library to the district if he were sure that there was a place where it would be properly looked after and housed. He cited the case of a law library, once left to the district, which I understand was rotting ingloriously in an attic of the Town Hall. Mr. Solon said that he was not going to have his library meet the same fate. This building was not completed until after he died.

I should also like to add a few words expressing my opinion that Sir Henry's scheme for deciding questions relating to the copying and registration of designs is far more likely

to get a fair and commonsense decision than in the Law Courts. I do not question the faith we have in the application of British Law. The Law Courts, however, do not seek justice: they do not seek the truth. It seems to me that the law is a game with certain rules, like the game of football, or bridge, or chess. The game must be played according to those rules. In important cases I have seen the players drop the business of taking evidence and discuss whether certain evidence is to be admitted, or not to be admitted. They do not ask if the evidence is true or false, but they ask if it is in accord with the rules of the law game. As a result the courts may get the truth, even though they are not after the truth. They are after the logical conclusion to be drawn from such evidence as can be admitted according to the rules of the game. I therefore strongly support the tacit implication in Sir Henry's suggestion that a committee of shrewd business men is far more likely to give a fair commonsense ruling on the questions under discussion than is likely to obtain in a game of law.

Proceedings of the Refractory Materials Section of The Ceramic Society.

Meeting held in the Technical College, Swansea, on Thursday, the 17th October, 1918. Chairman:—Sir W. J. JONES. The following papers were read: "Notes on the Distribution of Refractory Materials in South Wales," by Mr. J. Allen Howe, B.Sc., F.G.S.; "Magnesite as Raw Material," by Mr. T. Crook; "Silica Brick Manufacture," by Mr. G. W. Mottram; "Corrosive Action of Flue Dusts on Firebricks," by Dr. J. W. Mellor and W. Emery; "Study of Silica Products (Part II. Bricks, etc.)," by Dr. A. Bigot. In the evening the members and a number of invited guests dined at the Metropole Hotel, Swansea. The Vice-President (Sir W. J. Jones) in responding to the toast of "The Ceramic Society," said:—

Before coming here to-night, I was wondering what I could say, but then I remembered that my father's father hailed from Wales, and that I could surely count upon your indulgence in such circumstance.

Then I thought of my first journey to South Wales after I had taken up the position of Director of Refractory Materials at the Ministry of Munitions; how I met all the silica brick-makers of South Wales in this very town for the first time; how they all responded to my urgent call for a larger output when our position was extremely difficult and precarious; their kindness and consideration knew no bounds. I shall always cherish the memory of that meeting. The good feeling has continued till this time, and I feel sure it will endure.

You must forgive me if I fail to speak in the abstract, but I find it difficult to detach myself from the work which has fully occupied me for the past 2½ years, and after all it is the work in which we are jointly interested, and before which time I was unknown to most of you.

Well, gentlemen, the Welsh silica brickmakers have lived up to their promises made to me, and it may interest you to know that in July, 1916—when I first met them—the monthly output in terms of 2½ in. silica squares was 2,155,000 bricks. In November of last year the month's output had reached 3,780,000 bricks, an increase of over 75 per cent. I mention this because it shows clearly the extent to which the steel and

other industries, not of South Wales only, but of the whole country, were indebted to the efforts of the Welsh makers.

Nor are these remarks to be taken as confined to South Wales. The makers in North Wales have done well also, probably under more difficult conditions, and the figures that I have quoted are inclusive of all the Welsh makers.

The trade is an important one, and should be developed. With ample, indeed unlimited supplies of suitable raw material, obtainable from the Millstone Grit and extending from Glamorganshire in the south, to Pembrokeshire in the west, and to Flintshire in the north, and with further supplies from the Pre-Cambrian quartzite rocks of Anglesey, there is no reason why the silica industry in Wales should not be considerably extended, the more so as the cost of winning the stone is extremely low, and the facilities for export and transit are very favourable.

My criticism of the Welsh silica brickworks is that there are too many of them, nearly all of comparatively small units. They require to be reduced in number, and increased in size and efficiency. They have enjoyed good times during the war period, there are good times ahead for them for some years, afterwards there will be a slump in all probability.

It is important that the silica brickmakers keep themselves strong by cutting down the costs of production and of establishment, and this can best be done by reducing the number of individual units, by concentrated and enlightened management, and by constantly improving the methods of manufacture, with no fears or hesitation about being progressive.

For instance, we hear a very great deal about the inversion of quartz into tridymite and cristobalite, with successive increase in volume and reduction in specific gravity—in other words with accompanying expansion.

I have heard all sorts of arguments adduced against the precalcination of the silica rock before it is ground and moulded into the brick form, but I am not yet convinced that it is wrong, and so far as I know experiments have not been carried out thoroughly and persistently on a practical scale to prove that it is wrong. Obviously from some points of view it would be very advantageous to eliminate the major portion of the expansion by this means, in the same way as the burning of fireclay into "grog" and its subsequent incorporation into the firebrick or retort decreases the contraction in the finished article when in work, and the attendant disadvantages arising therefrom.

I believe Dr. Mellor is rather in favour of precalcination of the stone. I know I consulted him some four years ago

when my partner and myself prepared the plans for a silica brickworks, with continuous precalcining kilns, and Dr. Mellor approved. The additional cost would not be heavy, as by using a continuous process you would maintain your kilns at their full calcining temperature, and arrange for a continuous discharge of the calcined silica rock.

In other directions there is much practical investigation to be done. For instance, has the effect of a highly refractory neutral binder been considered, instead of the lime bond ordinarily used?

It is far easier for large and strong progressive concerns to work out on a practical scale such questions as these—aided always by the scientist—than for comparatively small firms to spend time and money in such investigations. For these and other reasons I advocate the fusion of interests, in order to put the trade into a strong position.

There is no need to fear that such a course would result in excessive or extortionate charges. There is no shortage of raw material, and any attempt to take such a line would at once re-act upon the guilty parties, as the consumers of the commodity would speedily arrange to provide for their own needs.

Another point upon which I should like to touch is that of standardization of patterns, and my remarks apply not only to silica, but to fireclay and other refractory materials.

I know of no industry so lacking in all efforts to standardization of designs.

What is there to prevent not only silica and ordinary firebricks, but blocks, tuyeres, and such specials being much more standardized?

Why should there be hundreds of patterns of nozzles and stoppers for ladles? I took the trouble recently to obtain from five firms the numbers of different patterns and sizes they made, and they totalled to 160 nozzles and 112 stoppers! It seems ridiculous to suppose that the reasonable needs of steelmakers cannot be met by anything short of 272 patterns of spouts and plugs for their steel ladles.

In the same way it should be comparatively easy to reduce the number of patterns and sizes of blocks and bricks for blast furnace linings. I am convinced that an intelligent study of this question would result in the evolution of a series of patterns which could be made applicable to practically any size of blast furnace without any detriment whatever to the furnaces themselves, whereas now each ironmaster has his own patterns, many of which are far too complicated, as well as some pieces

being far too large and heavy, without any corresponding advantages to be gained therefrom.

The same remarks apply to stove bricks or chequers, and many things of common use in steel and ironworks, gasworks, boiler houses, etc.

The Ceramic Society has prepared recently a series of proposed standard methods of testing refractories, and invited kindred societies to consider and criticise with a view to the general adoption of a series of tests. The Iron and Steel Institute are now considering the proposals, and I believe also the Institution of Gas Engineers—both of which organizations represent very large consumers. This will make for the good of both purchaser and supplier.

I suggest a committee should be appointed and get busy by making a serious attempt to standardize such articles as I have mentioned. We have engineering standards for goods in iron and steel (such as pipes, girders, tubes, rails, etc.), why not for refractory goods? It can be no disadvantage either to purchaser or producer, on the contrary it gives wider scope to the purchaser, ensures more prompt deliveries, and is more profitable to the maker, enabling him to reduce his pattern shop and upkeep costs, and ensuring increased output, while allowing him to reduce his selling prices, without affecting his profits adversely. Further, it induces co-operation, which is desirable in every form of business, and will continue to grow with all enlightened firms.

This all leads me to another aspect of the industry, which I desire specially to emphasize. I have taken every opportunity to preach the need of scientific investigation, of the advantages which obtain when manufacture and science proceed hand-in-hand.

This great war, this world war, has taught us the need of science and its general application to our daily methods. If it has not, then we have failed to learn the lesson, and will suffer in consequence.

What is science, but the methodizing of human experience, the application of acquired knowledge to give the maximum result? The classification of what we call Nature's laws, or what in other words might be described as the methodical use of intellectual conclusions, the intense and constant utilization of discovery and development.

If you concede this view, then let it be your first care to scientifically train your young and promising employees. If you discover a lad or young man in your employ who takes an intelligent interest in his work and yours, take care to encourage him, give him every opportunity of studying the

technology of clays and refractories: provide for a systematic training of the mind. It will be your best investment.

I wonder how many young men have been sent by our refractory makers to a suitable technical school or colloge to acquire such a training as I have indicated—very few I venture to say. It is altogether wrong. If you encourage your own promising employees, and study their future by helping them in the way I have named, they will prove their value to you in later years, and you will enjoy the satisfaction of having improved their lives and future outlook, with probable pecuniary advantage to yourself while so doing.

May I say that The Ceramic Society will welcome contributions to its Proceedings in the way of papers at our half-yearly meetings from managers of works? I have heard it said that many of our papers are ultra scientific; let us combine the scientific with the practical by having both types of papers. I hope proprietors of works will adopt my suggestion and encourage their practical managers to contribute papers at our meetings.

Every subject is the better for full and open discussion, we are all gainers thereby, including the contributor of the paper.

There may be such things as are known as "trade secrets," but they are illusory in most cases, I do not say in all. More often than not, however, a man discovers that what he thought was his particular secret has been known and applied by somebody else for a long time. I mention this because we are anxious to obtain the full co-operation of principals in assisting to persuade managers of works to read papers giving their experience and suggestions without restraint or reservation of any kind.

I commend to your reading the report of Sir John J. Thomson's Committee—published early this year—on the neglect of science in the educational system of this country.

It is pointed out in that report that in 1912–13 (the last year for which statistics are available) only some 4,000 matriculated students in this country were taking the applied science course, as compared with 12,000 German students.

There is much to be done in every direction, and you must call in the aid of science every time; as I have said science is but the methodizing of human experience, it never stops still, but always forges on. Whether you want to improve your mixtures, your moulding, your burning, it is all the same, you must apply knowledge to obtain improvement, to effect economy. And is not every effort of ours bent to obtain increased efficiency, which is really economy? That is the outcome of scientific application. The brickmakers in this

country can well apply scientific knowledge to the design and construction of improved kilns, especially at this time when coal conservation is of such great moment (important at all times), and they can seize the opportunity to make of themselves 25 per cent. patriots, a most excellent philanthropy for a commercial concern!

Look at the opportunities which the future holds for the makers of really first class coke oven bricks, scientifically graded, synthetically built up, to withstand the action of salt and other deleterious substances contained in the coal to be coked in the ovens. Hitherto in this country there has been a lack, amounting almost to an absence, of scientific application in the direction I have indicated; the coke oven brickmaker has taken but little heed of the varying compositions of the different coals to be treated—he has worked empirically, without chemist or laboratory, and in consequence has fallen hopelessly behind the German or Belgian coke oven brickmaker.

I have had a very striking, certainly a very disappointing, experience recently. A firm of coke oven builders refused to stand by their guarantees unless they could obtain the oven wall bricks from one particular firm in this country. Circumstances prevented me from consenting to their obtaining them from this firm, and although I offered them the choice of practically every other maker in the kingdom they steadfastly refused to accept full responsibility. It had been their practice before the war to obtain their requirements from abroad.

This discloses a deplorable condition of affairs here, and indicates quite clearly that there is a promising field for exploration to any firm or firms who are prepared to go thoroughly and scientifically into the manufacture of oven wall bricks, adapting the composition of such bricks to best suit the varying kinds of coal to be treated.

It is admitted that this country is not worse placed as regards raw materials than either Belgium, France, or Germany —on the contrary. It is the lack of application of scientific knowledge in the composition and manufacture that is the cause of our failure.

Incidentally I would remark here that one well-known firm of coke oven builders has recently confirmed the opinion which I expressed at our Sheffield meeting, and they are now building their oven walls of what I termed "straight silica" bricks and blocks, and this for the carbonizing of salty coal. Their experience so far is eminently satisfactory, and they are building other ovens of similar materal. I am well aware that difficulties remain to be overcome in pursuit of this practice, but they are not insuperable by any means; the chief trouble lies with the

expansion of the material, but this can be minimised if the material is kiln-burnt to a higher temperature and for a longer time than is the practice at present

There is a great and profitable field to be explored in connection with the making of bricks and blocks suitable for the construction of spelter roasting and smelting furnaces. This is a subject of much interest to this district. The material requires to withstand continual severe and rapid changes of temperature, without movement, and also to resist any chemical action due to the liberation of sulphurous gases in the roasting process. I am quite sure that scientific systematic research will well repay the enterprising manufacturer. The Ceramic Society will gladly lend its assistance towards solving the problems indicated.

You are well aware of the large extensions that have been undertaken of the steelworks of this country, not confined to any one district, but on the contrary well spread over all the steel producing areas. These extensions for the most part are for the production of steel by the "basic" process, from low grade home phosphoric ores.

The ingot capacity of the country will be about 12 million tons when the extensions are completed (which will be very soon) as compared with a pre-war output of $7\frac{1}{2}$ million tons.

I think the "basic" process has come to stay, and will in future account for 50 per cent. of our steel output. The only weak link in the chain is the absence in the country of suitable magnesite for the making of bricks for the basic steel furnace hearths. Hitherto we have not shrunk the imported raw magnesite completely at the first burning. I am hopeful that this will be remedied in the future, as a project has been settled for the erection of efficient calcining plant forthwith.

You are aware that in connection with the "acid" process of steel making it was the practice before the war to import large quantities of high silica sands from Belgium, France, and Holland, for use in the acid furnaces, as well as for steel foundry work, glass making, and other purposes.

The Ministry of Munitions took steps to alter this, and procured the valuable assistance of Professor Boswell, the well-known geologist of Liverpool University and the Imperial College of Science and Technology. This gentleman has made a systematic survey of the country, and I am glad to say that as the result of this action this country will be able, in future, to be self-supporting, as many valuable deposits of suitable sands, not hitherto worked, have been located and developed.

I have arranged for the work of Professor Boswell to be published. The memoir is now in the Press and will be ready

very shortly, and I feel sure it will be found to be of great service to the steel industry of the country.

I referred at our last meeting to the possible value of zirconium and its compounds: as a refractory, as an alloy in steel and other metals, as an enamel, and in other ways. I am glad to be able to report that the Advisory Council of the Committee for National Scientific and Industrial Research has agreed to devote some of its available funds to an enquiry into the possibilities and uses of this material, and the Ministry of Munitions has agreed to co-operate in the work. I am very hopeful of the result.

I mention these matters to indicate that although it was found necessary, owing to war exigencies, that a certain measure of control over the refractory materials industry should be exercised, such control has not been entirely arbitrary, or one-sided. On the contrary, speaking as a servant of the Ministry, I think I can claim that every effort has been made to exercise what one might term a "beneficial" control, imposing only the minimum amount of restraint over the trade while securing the objects necessary to be attained, but at the same time promoting the welfare of the industry as a whole. The Ministry has made every effort to carry the manufacturers with it and treat them generously and impartially.

Well, gentlemen, this brings to one's mind the question as to what is to be the future of the refractory materials industry in this country, and what steps are necessary to be taken to safeguard the industry after the conclusion of this present devastating war?

At Glasgow, a year ago, I ventured to express the view that the dawn of peace was faintly visible. I was wrong, the defection of Russia changed the whole situation against us. To-day, however, I think we may hopefully look out upon the horizon—we feel less anxiety than we did six months ago—the advent of our American cousins, the pooling of Allied resources for the common weal, coupled with a unified command, have given us the strategical initiative, and our enemies are now on the defensive, we trust till the end, when right will have vanquished brutality and wrong.

Then will come what has been described as the "reconstruction" period.

I am aware, I have heard it stated often, that many people are of opinion that matters should be allowed to settle themselves after the war, that we should permit things to slide into their old ways, in other words, a policy of "laissez faire" is advocated, as though there were no after the war problems to be solved.

If such a course was followed the lessons of the war would have been lost upon us. Our bounden duty, as well as our interest, is to look ahead and consider our position after the war; to lay our plans for peaceful progress, and for an intense, a relentless commercial warfare.

How can this best be done?

It is recognised that the interests of the refractory materials industry are identical with, bound up with, the interests of the iron and steel trade.

Let us, therefore, refer for a moment to the reports of the Reconstruction Committees appointed by the Prime Minister, the Board of Trade, and the Ministry of Munitions to consider the position of the iron and steel trades after the war.

These reports all point to the same ends:—

1st. The necessity for large and financially strong manufacturing concerns, well and economically managed, so as to reduce production costs and be in the most favourable position to compete internationally, and to maintain their works and plant in a high state of efficiency and be able always to take immediate advantage of scientific discovery.

2nd. The necessity for a much greater effort towards standardization of essential products. I will not enlarge upon this recommendation, which I have advocated strongly already.

3rd. The necessity for a much better understanding between masters and men. It is suggested that this can be done in various ways, such as the formation of one single trades union for each industry instead of a great many, as at present; the formation of a Board of Conciliation and Arbitration; the settlement of local differences by Joint Committees; mutual undertakings by masters and men to suffer penalties for breach of agreement, such penalties to extend to individual members of the respective associations; the establishment of piece rates wherever possible; the formation of Works' Committees representative of employers, foremen and workmen, to deal with local questions of labour, output, etc.

There is really nothing suggested which differs very much from the policy which I advocated over a year ago at Glasgow. Certain it is, however, that the interests of men and masters must become ever more and more identical, and it should not be beyond the wit of ordinary intelligent men, representatives of both sides, to devise some perfectly equitable and practical working scheme which will dispel all ill feeling and suspicion and make for smooth and amicable working. It greatly depends upon the spirit in which the problem is approached, as to whether or not a satisfactory solution will be forthcoming, but I am sure you will all agree that it is not only highly

desirable, but absolutely necessary to enable us the better to compete in the world's markets for that export trade which is the fundamental basis of national prosperity.

Rest assured that the days before us demand big views, big doings. The old moribund conditions are disappearing quickly, to give way to more enlightened progressive methods. The war has changed everything—our views have broadened involuntarily, unconsciously; the outlook has widened; the future possibilities are tremendous—domestic, industrial, national, imperial issues hang in the balance, and everything hinges upon the manner in which we tackle the problems which lie before us. The domestic and the industrial are bound up together, we shall see a continuation, a great united and, I believe, successful effort made for better social conditions, and the employer who recognises this, and accepts it as inevitable and acts accordingly, will come through successfully and prosper.

Similarly, our national and imperial interests are bound up—we must resolve with inflexible determination to put ourselves in a proper position to serve our relatives and friends in the countries forming this mighty and glorious Empire, to secure their trade and preserve their goodwill, and also to obtain the trade of the other countries of the world by sheer merit and ability to serve these countries better than they can be served by anyone else.

These are worthy objects, to be secured by enlightened progress and scientific application, and The Ceramic Society will gladly do all in its power to creditably perform its share of such good work.

In reply to a toast to the Secretary, Dr. MELLOR said:—Not many days ago the nation awoke, rubbed its eyes, and began to see that while it had been sleeping the Germans had made much progress in industrial research. As a result, several of our key industries were seriously threatened with extinction, and some had actually departed East.

We have been making frantic and hysterical rushes to make up lost ground. Every hare-brained scheme is now regarded as a fit subject for research. For example, here is a report of a research which has come into the Secretary's hands, but it does not appear on our agenda. I therefore take the opportunity of apologising to the author for somebody's omission. This paper embodies the result of a research into a common prejudice. The author seems to have been the first man to question the truth of what most people regard as very obvious, by asking: Does a cracked pot ever break? Most people say that a cracked pot never breaks. If this is right, it will be

obvious that we have at hand a means of manufacturing unbreakable pots. I may say that after a prolonged and costly investigation the author comes to the conclusion that cracked pots do really break, and that oftener than uncracked ones.

Without going into details it is rather interesting to recall that hard porcelain was made in this town of Swansea very soon after the mode of manufacture had been discovered in Europe, but the atmosphere of Swansea does not appear to have been favourable, and the manufacture languished and died. For the last century virtually the whole of the hard porcelain industry has been confined to the Continent (France, Germany and Austria). Attempts are now being made to revive the manufacture in England. Why did your town lose the art?

A giant research scheme was promulgated in connection with refractory materials about a year ago. The scheme had many good points, but up to the present it has not yet fully developed. In its conception various universities were asked to indicate what researches they could undertake in refractories. The answers were instructive. Some seemed to imagine that the necessary qualifications were a willingness to do something, the possession of a gas muffle, and the ability to spell cristobalite backwards.

I take the heretical view that while the formation of research associations may be a step in the right direction, it is only a step. It will not give all that is needed. We are attempting to grow a vigorous plant in too short a time. The industries concerned want acclimatizing to the atmosphere of research. It is the spirit which quickeneth, and this is not to be purchased by a £10,000 grant from the Advisory Council. It will take at least a generation to leaven many of our industries with the spirit of research. This generation must sow for coming generations to reap. Research must not be a mere accretion on to the industries, it must not be an extraneous addition from without, but it must grow from within as a vitalizing spirit animating workmen and foremen, managers and directors.

We not only want a trained army of researchers, but we want this army to be backed up by understanding supporters. Such a small proportion of the ideas of the researchers are really productive that I am afraid some of those who are to feed the guns may grow faint and weary. In wild Nature we have found that

> . . . . of fifty seeds
> She often brings but one to bear.

The Patent Office records tell much the same story, so much so that these records have been regarded as a kind of foolometer for the country.

I should like to develop still further the idea I have suggested, but there is little time. The idea is not a new one to me. Over 12 years ago I emphasized the opinion that the best possible benefits which are likely to follow from the cultivation of research in our industries will not be direct material benefits from particular researches, but will follow rather from the spirit which will animate the whole. We are not going to cultivate this spirit by endowing national institutions, and erecting gigantic buildings on the Scilly Islands away from the industrial centres. The institutions must grow little by little in the very heart of the industries concerned.

It is no good resting, expecting to crib the results of the researches published by other countries. The Chinese rested; once in the van of civilization, where are they to-day? I am inclined to believe that if other countries were for a term of years to hand over the material results of their investigations to this country, our spirit of originality would soon be atrophied, we should become incapable parasites; they would gain, we should certainly lose.

On Friday, the 18th October, a short Business Meeting was held. The Minutes of the previous meeting were read and confirmed. In connection with refractories research the two following resolutions were carried unanimously: "It is our opinion that the time is ripe for the formation of our own Research Association, and we are willing to co-operate with any other approved movement having a similar object"; "That the Council of the R. M. Section take the necessary steps for the formation of such an association." It was decided that the election of officers should take place every alternate year. Dr. J. W. Mellor submitted the Second Report of the Committee on the Standardization of Methods of Testing. The following papers were read: "Zirconia—Its Occurrence and Application," by Mr. H. C. Meyer; "Refractories in the Zinc Industry," by Mr. J. A. Audley, B.Sc. During the afternoon parties of members visited the works of Messrs. Baldwins; The Swansea Vale Spelter Co., Ltd.; The English Crown Spelter Co., Ltd.; and The Port Talbot Steel Works. The meeting was brought to a close on Friday evening by Mr. Cosmo Johns, who gave a Popular Lecture in the Grammar School (open to the public), entitled "Science and the Local Industries." Votes of thanks were passed to the Authors of papers, the Authorities of the Technical College and Grammar School, the South Wales Local Committee, the Honorary Local Secretaries (Mr. E. Bradford and Mr. Thos. Ellis) and the proprietors of the various works which were visited.

Proceedings.—Session 1918-19.

A meeting was held in co-operation with the English China Manufacturers' Association in the Central School of Science and Technology, Stoke-on-Trent, on Thursday, 13th February, 1919. THE PRESIDENT occupied the Chair, the attendance being 55. The Chairman explained that the Council had invited Mr. C. F. Bullock and Mr. T. Poole in turn to occupy the Chair. After first accepting, both gentlemen had been compelled to withdraw owing to ill-health. The following new members were proposed:—Messrs. F. E. E. Lamplough, M.A., J. Wildigg, and S. Dogar Singh. Dr. Mellor read a paper entitled, "Recent Work on the Bone China Body." T. Poole (communicated), B. Moore, S. T. Wilson, A. Heath, H. Plant, H. E. Wood, and the Chairman took part in the discussion which followed.

A meeting was held in the Central Technical Schools, Stoke-on-Trent, on Monday, 10th March, 1919. THE PRESIDENT presided over a meeting of 31. Proposals were received on behalf of Messrs. A. V. Pimble, W. M. Boyd, R. F. Bullock, and A. E. J. Vickers. Dr. Mellor gave a short note on "Blue Glasses." A paper by Mr. D. Roberts, entitled "Nigerian Pottery," was read by Mr. W. Emery. Mr. J. A. Audley proposed, Mr. F. Turner seconded, and the meeting carried unanimously, a vote of thanks to Messrs. Roberts and Emery. A short discussion followed, in which Dr. Mellor, Mr. A. C. Harrison, and Mr. A. Leese took part.

A meeting was held in the Central Schools of Science and Technology, Stoke-on-Trent, on Monday, 14th April, 1919. THE PRESIDENT presided over a meeting of 33. The following new members were nominated:—Major R. S. Casey, M.C., D.S.O., Messrs. Robert Crow, H. Clive, G. Hodgkinson, A. W. Cooke, G. Fuji, J. Spotts McDowell, A. E. Gibbs, and G. H. Blenkinsop. Mr. W. Emery gave a short note on "A New Method of Testing the Corrosive Action of Frits on Firebricks." Messrs. A. G. Richardson, A. Leese, and T. A. Simpson took part in the discussion. The Assistant Secretary read a paper by Mr. N. B. Davies, entitled "Apatite as a Substitute for Bone Ash in the Bone China Body." Messrs. B. Moore, A. Heath, and Dr. Mellor contributed to the discussion. Dr. Mellor gave

a note on the "Heat Conductivity of Porous Materials and Heat Insulation of Kilns," and was followed by Messrs. A. Leese and A. G. Richardson in the discussion. A paper, entitled "The Casting of Heavy Pottery," was given by Mr. B. J. Allen. Messrs. A. Leese, W. Cleverley, and Dr. Mellor took part in the discussion.

The Annual Meeting was held on Monday, 12th May, 1919, in the Central Schools of Science and Technology, Stoke-on-Trent. THE PRESIDENT occupied the Chair, and the attendance was 38. The following resolution was passed:—"That new members, elected after the meeting, shall pay an Entrance Fee of One Guinea in addition to the Annual Subscription. Students may join the Society as Student Members with a subscription of 5/-, but they will not receive the TRANSACTIONS. After twelve months' membership a Student Member may become a member without paying the Entrance Fee." The Retiring President (Mr. R. Lewis Johnson) gave an address. Mr. Bernard Moore proposed, Mr. A. Leese seconded, and the meeting carried with applause, a vote of thanks to Mr. Johnson for his services during the past Session. The Council's Annual Report was read and passed. The Balance Sheet for 1917—18 was presented by the Hon. Treasurer and adopted.

Mr. A. Heath, the retiring Vice-President, was re-elected for three years. The retiring members of the Council were Messrs. B. J. Allen, T. Bates, C. Edwards, and A. J. Vaughan, and all offered themselves for re-election except Mr. Edwards, who was leaving the district. Messrs. B. Moore, Junr., B. J. Allen, T. Bates, and W. H. Lindley were elected for three years. Mr. A. J. Vaughan was elected for two years to fill the vacancy caused by the death of Mr. G. Adams. All other officers were re-elected. A vote of thanks to the officials was proposed by Mr. A. Leese, seconded by Mr. R. Lewis Johnson, and carried unanimously.

THE CERAMIC SOCIETY.

Annual Report, 1918—19.

There is nothing very special to report as to the routine working of the Society; the membership roll is:

Individual	...	...	540
Collective	...	...	52
Honorary	...	...	4

The Council has been hard pressed at times during the past three years, but thanks to loyal help on all sides it is hoped that we have had to face the worst. The Pottery Manufacturers' Federation has paid the Society's deficit of £367. The deficit arose largely on account of the increased size of the Transactions, the increased cost of printing, etc., and the fact that about half the cost of one year's Transactions has previously come from the succeeding year's subscriptions. We are making a special effort to keep each year self-contained. It was necessary to raise the subscription materially since it was found that the net cost of the Transactions last year was more than double the member's subscription, and it would not have been possible to continue without the generous aid received by special subscriptions.

A special but independent Art Section of the Society has been formed which promises to do an important service to the industry.

The Society mourns the loss by death of Mr. George Adams, Mr. Greville Jones, Mr. Thomas Taylor, and Mr. Hubert Wicks.

The Council desires to thank the Governors of the Central School of Science and Technology, Stoke-on-Trent; also the authorities of the Technical College and the Grammar School, Swansea, and the Literary and Philosophical Society, Middlesbrough, for the use of rooms.

J. A. AUDLEY.

12th May, 1919.

STATEMENT OF ACCOUNTS,

1917–18 SESSION.

Income.	£	s.	d.
Balance in hand (1916-17)	225	2	9
Members' Subscriptions ...	512	11	10
Advertising Department...	66	10	0
Grant from Manufacturers' Association	50	0	0
Grant from Wages and Conciliation Board, Stourbridge	30	0	0
Special Subscriptions as per Printed List ...	171	0	0
TRANSACTIONS Sold ...	196	15	3
Binding	0	7	6
Postages Paid	1	13	4
Sundries	4	5	8
Bank Interest	8	0	9
W. Donald, Esq.	98	18	6
Unpresented Cheque ...	0	11	5
	£1,365	17	0

Expenditure.	£	s.	d.
TRANSACTIONS, Vol. 16, Part 2	156	9	10
TRANSACTIONS, Vol. 17, Part 1	235	5	10
Blocks	79	17	9
Abstracting, 17 months ...	144	1	9
Journals	35	4	11
Binding TRANSACTIONS, etc.	19	4	3
Expenses of Meetings* ...	104	3	11
Reporting	6	18	0
Postages	69	16	11
Printing and Stationery ...	59	6	0
Typewriting Machine ...	39	4	0
Insurance	1	10	0
Cheque Books	0	11	0
Bank Charges	1	8	6
A. Rigby (Honorarium) ...	10	0	0
F. S. Worthington ,, ...	7	7	0
Miss Hulme...	5	0	0
Miss Lycett...	2	0	0
Grant to Research Committee, London	25	0	0
A. Heath, Esq., Advertising Department, Commission	5	1	0
Sundries	22	0	0
In Hand	336	5	10
	£1,365	17	0

As against the balance of £335 14s. 5d. there are estimated Accounts owing for £591 5s. 8d. to complete the Session 1917–18, thus showing a deficit of £255 11s. 3d.

Audited and found correct,

F. TURNER,
C. E. RAMSDEN, } *Auditors.*

November 15th, 1918.

*The high "expenses of meetings" were connected with the formation of the Refractory Section. By Min. 76, 14th May, 1918, Local Councils are now to pay the expenses of their own meetings.

Proceedings of the Refractory Materials Section of the Ceramic Society.

Meeting held in the rooms of the Literary and Philosophical Society, Middlesbrough, on Thursday and Friday, the 22nd and 23rd May. Chairman: THE PRESIDENT. At the commencement of the meeting on Thursday the Mayor of Middlesbrough (Joseph Calvert, Esq., J.P.) welcomed the visitors to Middlesbrough, and the Chairman thanked him for his kind reception.

The following papers were read:—"The Geology of the Refractory Materials of the North East of England," by Mr. J. B. Atkinson, M.Sc., and Mr. J. T. Stobbs, A.Sc., F.G.S.; "The Use of Mica Schist for Lining Steel Converters and Cupolas in America," by Prof. P. G. H. Boswell; "The Salts extracted from Coal by Washing," by Mr. W. J. Rees; "Some Criticisms by a Firebrick Manufacturer," by Mr. G. R. L. Chance; "Factors Affecting the Conversion of Quartz in Silica Bricks," by Dr. A. Scott; "On the Character of Bricks removed from the Roofs of Open-Hearth Furnaces," by Dr. J. E. Stead; and "A New Type of Recuperative Furnace," by Dr. W. Rosenhain and Mr. E. A. Coad Pryor, B.A.

In the evening the members and friends dined at the Cleveland Club, Middlesbrough.

SIR W. J. JONES, K.B.E., in proposing the toast of "The Trade and Commerce of Middlesbrough and District," said that this was a toast which he really felt himself unable to propose as well as he would have liked. The district of Middlesbrough in which they were met, not the town alone but the district, could probably show a growth with which no other district in the country was comparable. In 1821 the population was 25 persons; in 1841 it had grown to 5,460; and in 1891 to 75,000; to-day it reached 140,000. He doubted very much if there was any place in the United Kingdom that could compare with Middlesbrough in such a vigorous growth. He had on either side of him two distinguished citizens of Middlesbrough, on his right Sir Hugh Bell; on his left, the present Mayor, who had accepted the mayoral chair for the fourth successive year. Of course, as they were aware, the great industries of which Middlesbrough was the hub were the iron and steel industry, and that of

shipbuilding. The pioneers of the iron industry were, he believed, Mr. Bolckow and Sir Lowthian Bell, the distinguished father of Sir Hugh, whose work on blast furnace practice was still regarded as the standard. Sir Hugh had followed in the footsteps of his illustrious father, and he was described very well as the Mr. Joseph Chamberlain of Middlesbrough. The Mayor, on his left, who had devoted himself to public work and had done all in his power for the social benefit of the town, had given up his time and energy in promoting the welfare of the people. It was essentially a working-class population, and the present Mayor had done everything he possibly could to improve its environment. The speaker understood that the Mayor was a great authority on Housing questions as well as on every question which appertained to the welfare of the general population, and he was quite sure that the two gentlemen whom he had named could well be trusted to advance to the fullest extent possible the scientific education of the rising generation, which was of such importance to an industrial town like Middlesbrough. He was sure that they who had visited this town wished it great and continued prosperity, and in saying that he thought he was saying all. He asked them to drink "Prosperity to the Town of Middlesbrough," coupling with it the name of Mr. Calvert, the present Mayor.

The Mayor of Middlesbrough responded, saying he counted it a great privilege to be associated with this prominent gathering, and he was glad that, in proposing the toast, Sir William had departed a little from the printed toast, which was the "Trade and Commerce of Middlesbrough," and coupled with it the town as well as its trade and commerce, because, as a native of Middlesbrough, incorporated in the same year as the borough was incorporated, he was a little jealous when Sir Hugh Bell wanted to claim that the town was old, or getting old. As a native of the town he felt proud of what had been accomplished in Middlesbrough during his lifetime. He could remember that borough when all the erections were practically on the north side of the railway. To-day he supposed the residential part of the town extended over quite two miles to the south thereof. They had not a great deal to show in things that were ancient, though there were some relics of past days that were not without interest in their neighbourhood, but he thought there were in the town indications of progress and activity. They indeed prided themselves on being wide awake, but he wanted for a moment to turn to the trade of the town. Their principal industry, as Sir William Jones had said, was the iron and steel industry.

Some of them could remember when it was not steel at all but only iron, and those dark days of the '70s after the Franco-German War, when steel was coming in to replace iron and iron was not required, how hard a period they passed through in Middlesbrough; but the pioneers of the trade, the leaders of industry, at that time addressed themselves to the manufacture of steel, and he was glad to say that now they held the premier place amongst the towns and districts engaged in that industry. Might he say to those who had come to Middlesbrough for the first time, and to those who might be looking about for a good place whereupon to establish a kindred industry, that they would find them equipped with a great many things that might help them. They had good and cheap water and abundant supplies of cheap electricity and gas, and if they wanted sites of land he was quite sure that in responding to the next toast Sir Hugh Bell would be able to tell them where they could get them.

They were delighted to have amongst them such a distinguished group of the members of The Ceramic Society as were gathered there. This gave him the opportunity of saying that whilst in Middlesbrough ordinary elementary and secondary education had been well attended to, he deplored that they had not been in the van in relation to technical and scientific education, but now, through the beneficence of some of their business men and some of the large employers of labour, he was glad to say they were soon to have in their town a technical college which would be of great service, and perhaps a metallurgical research college, and he really hoped that in the near future Middlesbrough might take its place amongst the leaders of scientific thought. They were very much indebted to The Ceramic Society for honoring them with their presence, and they were specially thankful for the kindly words which the visitors had spoken.

The toast of "The Tees Conservancy Commissioners" was proposed by Lt.-Col. C. W. THOMAS, who said he did not think there could be a single member of The Ceramic Society who had attended that meeting who had not been struck with the extraordinarily warm welcome that they had received at the hands of the public bodies of Middlesbrough. He might almost go so far as to say that, immediately on arriving there, welcome was palpable in the atmosphere of the place. He did not think in saying that he was committing himself to any exaggeration. As a visitor, and one who had only been there a little more than 24 hours, it might perhaps be presumptous on his part to express an opinion about the work of the Tees Conservancy

Commission, at the same time he must say that he did not think anybody coming there for the first time and travelling down the riverside, passing the enormous works situated on its banks and seeing all the shipping facilities of the waterway, could fail to be struck by one thing, and that was, that the enormous progress of the Middlesbrough district was due to its water facilities. It was perhaps even more due to the way in which those facilities had been developed and made the most of by the Tees Conservancy Commission. This certainly expressed the opinion that had been formed in his mind since he arrived there. They must all be very much impressed by the amount of trouble and labour that had been expended by the Commission in order to make that visit a pleasant and successful one, and for that, he need hardly say, every member of the Society present was more than grateful.

The President had referred to one or two things which might equally be applied to the development work which had been done by the Tees Commissioners. One more thing, and that was, that he felt quite sure from the evidence that they had put before them of what had been done in the past towards the growth of Middlesbrough in the matter of steel and other ways, that what would be done in the future would be on an even bigger scale and of greater result. He thought that was a very sound deduction. He did not know whether he ought to indulge in contrasts, perhaps not, but one was almost tempted to ask the question how it was if one body of Commissioners could do so much for their particular part of the country, other and more recently constituted bodies of Commissioners did not seem to have achieved such marked success. He asked them to honour the toast of "The Tees Conservancy Commission," coupling with it the name of Sir Hugh Bell.

In responding to this toast Sir Hugh Bell, Bart., C.B., said he was much gratified to have once more an opportunity of returning thanks for an honour that had been done to the body over which he was proud to preside, and over which he had presided for a considerable number of years. He spoke in rather a chastened frame of mind, because it was just possible that he might never more have the opportunity of responding for the Tees Conservancy Commission. It seemed not altogether unlikely that a larger organization might be about to absorb the particular body over which he was proud to preside, and that before long they might find themselves a department of the Government instead of a self-governing body as at present. He ventured to deplore

that possibility, not because he did not think the Tees Conservancy might easily get a better chairman, but because he felt convinced that it would be impossible for a body not possessed of the intimate knowledge of the requirements of the district to administrate the river in the same way, and with the results that had been praised by Sir William Jones and Major Thomas. He thought there could be no doubt that the work which had been performed in the past was worthy of all the praise which the proposer of the toast had been good enough to give it. He thought that the desire to improve the river and make it the best vehicle of communication between the Middlesbrough district and the rest of the world had been the motive power to enable them to accomplish what they had done. There had, in the distant past, been difficulties of a local character which had rendered the course of the Commission not always perfectly smooth; but those had all been overcome, and he asserted without any fear of contradiction that an undivided and unselfish spirit actuated them in their desire to make the river the best that it could possibly be for the purpose for which it was designed, and that the spirit was not local in its character but national and international. One of the things that was claimed for the possibility of taking over such bodies as the Tees Conservancy and other similar trusts, was that there had been a tendency to look at the development and improvement of the locality rather than from the national aspect. On behalf of the Tees Conservancy, as well as on behalf of similar bodies with which he was acquainted, he thought he might safely assert that there was little or no trace of that parochial spirit.

But perhaps they were dealing with the matter in too solemn a way; let them turn to the lighter side. The Mayor had doffed his chain of office and his splendid robes and appeared before them in the capacity of a kind of a bagman. He might well take up the same line. His friend on his right had been enquiring whether they had certain commodities to sell, and he had referred Dr. Ormandy to the gentleman without whose mediation he believed the Tees would cease to run to the sea. He had often declared his belief that but for the continued attention which Mr. Amos gave to the matter it was very doubtful whether the waters which fell on the Pennine Range would succeed in getting to Middlesbrough and thence into the North Sea. He desired to point out that Mr. Amos had removed to Darlington in order to be quite sure that he got the water sent down. He need not tell Dr. Ormandy that in Middlesbrough they had indeed got precisely the commodity

he wanted, whatever that might be! A tall order—not taller than the circumstances warranted.

They had been good enough to say that they had been accorded a hearty welcome. He assured them that it only equalled that which was in their hearts to offer them. They had learned with great pleasure that The Ceramic Society contemplated paying a visit to the district; they felt that the Society was doing them a great honour in coming there, and, being always ready to learn, they felt sure that they would derive benefit from the Society's visit. They in Middlesbrough might not have as completely equipped technical institutes as they might desire, but he could assure them that they wanted to remedy that difficulty as soon as possible.

Now one of the subjects in regard to which he was going to profess ignorance was the question with which The Ceramic Society was formed to deal. He understood that although they were entertaining The Ceramic Society in general they were entertaining in particular the Refractory Branch of that Society, and refractories were something with which they had to deal all their lives in various forms, not only refractory to the influence of fire but also to other sorts of influences which became more and more in evidence as the years went on. He was glad that The Ceramic Society thought well of what they had seen in that district. They welcomed the Society very heartily indeed, and those who had arranged the programme of that evening had asked him to convey in the toast he was about to propose that welcome which he had endeavoured to express.

Sir Hugh Bell, Bart., C.B., also proposed the toast of "The Ceramic Society," and said he understood the Society was now in its twentieth year, that it was formed, as might have been expected, in those Midland Counties of England where the art and the manufacture of earthenware had had its home for so long, and held so distinguished a place in the history of English enterprise and English art, both in the more restricted sense of æsthetic art and in a larger sense of the arts of manufacture. That those persons who were engaged in working clays should have come to the conclusion that rule of thumb was no longer the only rule, or indeed the most important rule, to be applied to their art, was not surprising. Nor was it surprising that, having determined to form a ceramic society to deal with the problems of art and science in the manufacture of earthenware, they should have turned their attention to other sides of their industry and to that part of the industry which so greatly concerned them

in Middlesbrough. It was interesting to think that men, not so very old, still remembered the time when to have a very highly refractory material was not of such vital importance to industry as it was at the present moment. It was during the last few years that they come to command such high temperatures that such extremely fire-resisting materials had become a matter of such very great moment. Now to-day it might be said that there was hardly any limit to the temperature at the disposal of man. Questions which concerned the supply of material which would satisfactorily resist those temperatures had accordingly become of great importance in industry. The examination of the materials intended to be used at these high temperatures were consequently of vital moment. It was to study that very interesting subject that the Refractory Branch of the Society had come into existence, and he felt that it would be difficult to find a place in the United Kingdom where their studies were likely to be more highly appreciated or of greater use than in Middlesbrough. Therefore it did not seem at all extraordinary that they should welcome them in the warmest way in their power. He hoped their visitors would not find the Middlesbrough people refractory, but on the contrary as sauve and manageable as the plastic clay with which they had to deal. On the other hand when later Middlesbrough came to them and would supply them with materials as refractory as they could be when the occasion arose, and, if the one equalled the other, then he ventured to assert that the problem had been solved. They in Middlesbrough had found their visitors to possess those qualities in an eminent degree. When the time came to ask them to supply the result of these studies they hoped to find them to possess quite the opposite quality to an equal extent. If this were the case the problem was solved.

Sir William Jones:—I thank Sir Hugh Bell more than I can express for the kindly way in which he has proposed the toast of "The Ceramic Society," and the gentlemen present for the cordial way in which they have received that toast. We are met to-night for the fourth successive time under my Chairmanship but under far different and happier conditions than hitherto. At Glasgow, Sheffield, and Swansea, our meetings were very pleasant and enjoyable, but we were nevertheless under the restraining influence and anxiety of the great conflict which we have been for so long waging and were still waging with an implacable, brutal and unscrupulous enemy —for our very existence as a free nation.

To-day we feel the intolerable burden is at last lifted, and, while expressing our thankfulness to the Almighty for His protection, we rejoice in the knowledge that this country and the world at large is saved from the brutalizing influence of a powerful enemy who for long years has inculcated in its people the doctrine of Might alone being right; we meet to-night with lighter hearts and confidence in the future. We have passed through the long dark valley and have at last emerged into the sunlight, and we stand to-day overlooking the fair plains of promise, strong in our determination to go forward to win the battle of peaceful progress and to secure and hold the markets of the world, having learnt the lesson in the meantime that we must adapt ourselves more thoroughly than hitherto to the needs of our would-be customers.

This is absolutely necessary for our continued prosperity —we as a nation not being self-supporting must secure our full share of the markets of the world to enable us to pay for the food and materials we require to obtain for our existence.

Refractories manufacturers have played their part, a great and important part, in securing the victory to which I have alluded. Theirs is a key industry upon which all heat reduction processes have been dependent. I doubt, indeed, if before the war the great importance of the refractories industry was fully realised. I have done my best to inculcate into the minds of the "powers that be" the very real consequence of your work.

Before leaving this point perhaps it may not be out of place, nor altogether without interest, if I tell you in summary what the effort of the refractories manufacturers in this country has amounted to during the last two and a half years of the war, *i.e.*, from July, 1916, to the end of 1918, which was the period that I was in control of the Department at the Ministry of Munitions. I can only give you the figures for this time because I have not the figures in my possession prior to the time I took up the work.

Silica bricks amounted to the equivalent of 275,295,000 $2\frac{1}{2}$ in. squares, all of which were carefully allocated to strictly munitions output.

Silica sand for steel furnaces—49,600 tons.

Magnesite bricks amounted to the equivalent of 15,089,900 $2\frac{1}{2}$ in. squares, and all of these also were allocated for nothing but munitions purposes.

Coke oven bricks amounted to 150,222 tons, or 50 million bricks, all for coke ovens whose output of coke was scheduled, and most of which ovens had bye-product recovery plants attached thereto, for production of benzol and toluol.

Firebricks totalled 3,585,475 tons, or, say 1,200 million bricks, and this figure only includes the returns from those firms whose work was practically entirely devoted to munitions output.

Raw dolomite was 127,000 tons, and calcined dolomite (known as basic material) amounted to 410,500 tons, the whole of which was used in the steel works producing steel by the "basic" process, as distinguished from the "acid."

During the two and a half years under review the percentage increases between July, 1916, and the maximum output in any month amounted to the following:—

Silica bricks	45	per cent.	increase
Magnesite bricks ...	149	„	„
Coke oven bricks ...	110	„	„
Firebricks	41	„	„
Raw dolomite	60	„	„
Basic material	70	„	„

Much progress has been made during the past 4½ years—but far more remains to be done.

We start our peaceful campaign with an enormous advantage possessed by very few other industries, in as much as we have not suffered dislocation during the war period, as compared with other trades. The turn over has been more easily and readily accomplished than in almost any other key industry, speaking generally also the refractories manufacturers have all emerged from the war period in a stronger and more robust condition, notwithstanding the exacting trials they have had to pass through in having to meet Excess Profits and Income Tax!!

The trade should go forward fully resolved that not a single brick of whatever character shall in future be imported into this country, whether it be from our Allies, France and Belgium, or our late enemies Germany and Austria. There is no need for any such importation. It requires only a firm resolve to produce the needs of this country in their entirety, and to immediately put into operation the necessary machinery to this end. In other words, to take such steps as shall ensure that the quality of the product is fully equal to the foreign article, for the particular purpose for which it is to be utilised

There can be no question of the advantages possessed by the home producer having in view the heavy item for transport on refractory materials, which are unlikely to become lighter under the clogging influence of State direction without competition of any kind. So that provided the manufacturers of this country do provide an article equal to that produced abroad all should be well.

There is never any difficulty in selling a commodity of the best quality of its kind, and the tendency to purchase the highest quality is growing—people recognise the economy of such practice which becomes more evident as labour charges increase. It should be your earnest endeavour, therefore, to attain to such a position of excellence.

You will have to face the inevitable in regard to higher wages for the workmen, as they become better educated and better organized they will naturally require improved conditions of life and surroundings, and they will be in a position to exact better terms. On the other hand increased production must be obtained to enable this to be done, and it is the correct way.

Unless we succeed in obtaining continuously increased production, which means relatively lower cost, we cannot compete with other nations, and as most trades are inter-dependent and are affected the one by the other, the obvious necessity is that the refractories industry must be in the van in this regard. If the steel, non-ferrous and chemical industries do not prosper the refractories industry cannot, and if it is necessary for these great industries to reduce their cost by increasing the production per man employed, so the refractories industry must do its share in the same direction, always without sacrificing quality, but on the contrary seeking to improve it.

I have just returned from a month's journeying through the centre and south of France, through the restored provinces of Lorraine and Alsace, and through the occupied territory of the Saar Valley, and I find the conditions there as regards labour and wages certainly no better than here at home.

In France the wages of men employed in making refractories have increased by at least 100 per cent., in Lorraine the whole of the workmen in the steel industry have received advances amounting on the average to between 100 per cent. and 150 per cent. on their pre-war earnings, and in Saar District the advance has been greater, except where the employers have fed and housed the men, where the advance has been less because the greatly increased cost of living has not been raised on the men but has been borne by the employers, who to-day are supplying meals of sorts at a purely nominal figure. Certainly the cost of food and articles of necessity in the occupied German territory is enormously higher than here—after making all allowances for exchange—and there is still very little to be obtained, although the French are quickly improving matters in this regard.

Moreover, the eight-hour day is now established by law in all these districts, in place of 12 hours previously obtaining, and this reduction of hours is not accompanied by any basic

reduction in daily or weekly rates of pay, with the increases which I have named already.

While in France I took the opportunity to visit two very important refractories works, one in the neighbourhood of Lyons, and the other in the centre of France, this latter works being quite modern and having been entirely erected during the years 1917 and 1918.

I was impressed with the extraordinary care that is taken in every single operation—everything is done with remarkable accuracy. The clays employed in the manufacture are some eight in number, and are obtained from all parts of France—some from the north, some from the centre where the works are situated, and some from the extreme south, close to the Pyrenees.

All the clay, not previously burnt for grog, is carefully dried on heated floors on arrival at the works, and is broken down through jaw breakers, and steel crusher rolls, and passed and repassed through screens of different mesh according to its nature and its function, to secure exactitude and regularity of grading. The grog is treated in a similar manner. All grog is burnt in special gas-fired kilns to cone 14. The firm uses a dozen or more different mixtures according to the uses for which the bricks or blocks are to be employed.

The percentage of grog carried in the bricks often runs as high as 70 per cent. and even 80 per cent. The mixing is done to an exactitude, and the precise proportion of each quality and grade of raw and burnt clay is introduced by means of measuring barrows into circular mixing vessels fitted with revolving arms and carrying mixing blades and hinged ploughs. The mixing is first done dry, and when thoroughly completed water is added of just the required quantity and a further wet mixing takes place, after which the material passes through a pug.

The moulding is carefully looked after in every detail, the drying is by means of tunnel driers and the burning is done in gas-fired continuous kilns, with recording pyrometer fitted thereto. The temperature obtained is 1,450° C. (say 2,640° F.), which is held for 36 hours.

The works are laid out in units. A capable chemist is installed in a well-equipped laboratory. They obtain high prices for their products, and have more orders offered than they can execute. I mention these facts to show you how very different is the method of working just briefly described, compared with the practice followed in this country for the most part.

This may be thought by some of you to be somewhat a digression, but it occurred to me that it would be of interest to many of you, and would enable you to form an idea of conditions obtaining abroad, although it may not strictly be in order in replying to the Toast of The Ceramic Society.

But my own view is that The Ceramic Society should identify itself with any and every movement which may have a bearing upon the refractories industry, and assist in furthering its prosperity. Particularly is this the case in regard to the improvement in the processes adopted for manufacture of refractories, and the betterment of the quality of production, which brings me to the particular movement which is at present very near my heart, and in the great success of which I am most deeply interested. You have on previous occasions patiently borne with me while I have administered what has been very much of the nature of a lecture as to what you should and should not do to improve your industry, according to my lights, and I appreciate very much the tolerance you have shown me on all occasions.

To-night I am going to make a very serious appeal to every one of you to support to the fullest extent in your individual power the new Refractories Research Association which has been formed at your instruction, and, by giving it support to the utmost of your capabilities, you will be rendering yourselves the greatest possible service both individually and collectively.

I want to impress upon you the need for taking a very big broad minded attitude in this matter. Pray do not look at it from the purely personal or (or if I may use the expression inoffensibly) from the selfish point of view. It is not possible for every manufacturer of refractories to be able to equip a laboratory and employ one or more research chemists to study questions which directly affect the quality of the output of such manufacturer, and even if it were possible there would be an enormous overlapping of work which would be a great waste of effort and expense.

Rather should there be a proper spirit of co-operation throughout the industry, a resolve to take such steps as may be considered wise in the general interest of all concerned, and the formation of this Refractories Research Association appeals immediately to that spirit of proper co-operation, which I desire to see grow in strength.

Men are generally ready to come together to form mutual protection associations, to keep up selling prices, to withstand the wages increases demanded by workmen. These are of a more or less negative benefit. The formation of a strong

Research Association for the benefit of the industry as a whole is of a much more positive character—the setting up of an organization controlled by a practical, responsible, and trustworthy Committee appointed by the members and under the technical guidance of the best expert available, is surely something which will benefit the manufacturers—which will point out to him where and how he can improve the quality of his products, where and how he can economise in his costs, where and how he can increase his production. It affords suitable food for the very roots of his business.

No man here is so egotistical as to think for a moment that the quality of his products is incapable of improvement, that his working costs of production are reduced to the lowest obtainable under any conditions, or that his productive capacity cannot possibly be increased.

No man here is so short-sighted as not to see that a general improvement in quality, a general reduction in working costs, or a general increase in output is going to be beneficial to him as well as to the industry as a whole.

Scientific discovery is not going to stop, nor improved methods of utilizing and adapting such discovery, and therefore, it is manifestly to the interest of every one present, to support generously the effort which is now being made to firmly establish a Research Association for your industry.

The project has crystallized; meetings of the Committee appointed by the members of this Society have been held; application has been made to the Privy Council Committee for Scientific and Industrial Research for their support, which has been obtained.

The man most capable to direct the work of such an Association has agreed to accept the position of Technical Director. I mean our friend Dr. Mellor, to whom this Society and every individual member owes so much, and whom it is our bounden duty to support in the fullest measure possible.

Dr. Mellor estimates that the amount of money required for the first five years, to put the Association on a sound basis, and to enable it to carry on the work which is desirable and in the general interest of the trade should be undertaken, will be £6,000 per annum.

Of this amount the Privy Council Committee for Scientific and Industrial Research will find one-half, so that my appeal to you to-night is to provide £3,000 a year for the next five years, as a minimum, surely a comparatively small sum for those directly and indirectly connected with the industry to provide. By this I mean that the subscriptions are not confined to manufacturers of refractories. We have as members of this

Society a large number of very important consumers and they will benefit directly from the success of this movement, and therefore I appeal to them with confidence to support this scheme by becoming members of the Research Association, which will entitle them to all knowledge of the work done, and the results obtained, and which will also enable them to have special work in which they may be directly interested to be carried out at their cost, and for their own benefit.

Incidentally I would remark that any subscription to the Association as constituted is recognised by the Government as a legitimate working cost against the business of the subscribing firm, and is not subject to Excess Profits or Income Tax.

Let us consider for one moment the nature of the work that lies before us.

The careful study of the raw materials employed in the composition and manufacture of refractories; their purification, and their blending to suit particular trades and conditions.

The chemical, physical and mechanical problems to be investigated to yield the best results, or in other words to be applied to such raw materials to render them in such forms as to obtain the maximum value and efficiency from same, and which will involve the careful study of their chemical and physical properties, and their treatment in every branch of manufacture (grinding, grading, mixing, moulding, burning, etc.), and their fitness for different uses, whether it be in the steel smelting furnace, the heating furnace, the blast furnace, the coke oven, the gas retort; whether for employment in the copper, zinc, brass, glass, or any other industry requiring heat treatment.

Then the effects of different kinds of slags and impurities of molten metals, of acid and alkali reactions on the materials employed have to be studied; the effects of quickly changing temperatures; the erosive action of flue dusts carried forward in the heating gases; the cutting action of high temperature flames from heating gases under varying pressures; the effects of oxidizing or reducing conditions, and many other considerations involving the careful study of such problems as conductivity, porosity, contraction, expansion, density, hardness, softening points, effect of load, and so on.

These are only a few of the subjects to be carefully and systematically investigated, and the knowledge thus obtained to be utilised and applied for industrial benefit and improvement, but I am sure it is unnecessary for me to detain you longer in order to convince you of what great benefit to the industry as a whole, and to your own particular business, such a Research

Association will be if properly conducted, and worthily supported.

The Ceramic Society is eminently fitted to take a prominent part in such an important work, it desires to co-operate with any other organization or organizations whose interests may lie along the same lines; it has no selfish motives, but a genuine desire to promote the interest of both makers and consumers of refractory materials.

No greater compliment could be paid to Dr. Mellor, and nothing would give him greater pleasure, than to see this Refractories Research Association firmly established and enthusiastically supported by manufacturers and consumers alike. Dr. Mellor has no greater interest in life than to see the industry for which he has done so much, and withal so unselfishly, continue to grow strong and prosper, and he regards this movement as in every way desirable. Certainly The Ceramic Society's good work in the past would be rendered of even greater value in the future.

If I may be allowed to add just one personal remark it would be that I should like to feel that this Association had been firmly established during the time that I had occupied the office to which you have done me the honour to elect me, and I should regard it as a fitting Peace Memorial on the part of the members of the Refractories Branch of The Ceramic Society, and as an earnest of their determination to press forward a movement which could have no other result than to place this country in a better position than hitherto to hold its own with the other nations of the world, and assist in securing to the trade of this country the reward to which it is so well entitled after all its labours and sacrifices in the cause of progress and enlightenment.

In proposing the toast of "Kindred Societies" Dr. W. R. ORMANDY said that the guests at a dinner such as that might be divided into two groups, those who were allowed to enjoy their dinner, and those who had to get up to say a few words. They had heard a good deal, and he agreed with all that had been said with regard to the ability and service which Dr. Mellor had given to the Society; but there was another aspect of Dr. Mellor; he inveigled him into giving a popular lecture, and the thought of that lecture had almost caused him to lose some sleep on the previous Sunday afternoon; then at an expense of tenpence he sent him a telegram asking him to propose that toast and consequently spoiled a good dinner. Fortunately he noted Dr. Mellor was an honorary secretary, they did not pay him for doing that sort of thing. Despite all that, he

was very pleased to think that Dr. Mellor had given him the opportunity of presenting that toast because he happened to be a member of a considerable number of those sister societies, and, living as he did in London, he had to attend a good many committee meetings and council meetings of scientific societies. This was sometimes a good excuse for getting home late. The Ceramic Society was a comparatively young body, and before it existed there were many other societies who made use of their products. The chemists required stoneware and porcelain in order to carry on their researches; electrical engineers required their porcelain; the iron and steel industries could do nothing without them, consequently they had been, like the middle classes are to-day, in the hands of the profiteers. Then came the formation of The Ceramic Society, and although they were only 20 years old they felt they were now in a position to speak on a level footing with many of those kindred societies which had been longer in existence, and they realised that their prosperity was in a considerable measure bound up with their own, and that therefore, even from a small and selfish standpoint, they were bound to wish them health and prosperity. They wished them that, of course, from a much more altruistic standpoint, but at the same time it should be pointed out that all industries were so interlocked that not one of them could prosper without progress on the part of the others, and the idea that learned societies merely existed for the purpose of discussing dreary subjects, in a dreary manner, was entirely wrong; those societies were the mouthpiece of those on whom the progress of the whole universe from a material standpoint was depending. They had heard that evening that the town of Middlesbrough had not yet converted the cash which it had acquired into provision for higher education. He would like to point out that no number of millions spent on ordinary education, or higher grade education, were of the slightest use in leading directly to real scientific progress. This was merely a means of educating a large number of efficient tools and of giving one in a thousand of the multitude a chance of climbing the ladder of higher education; but he would point out that there was one in ten thousand, a man of genius, who was able to use the tool of higher education. These were the men who directed all men beneath them, and it was only from these men that real progress came. He mentioned this because it had a direct bearing on the subject which the previous speaker had dealt with—the formation of an association for research connected with that industry in which they were all so interested. Money spent in that class of educational work was more likely to lead to immediate and tangible results than much larger

sums spent in a much more showy manner, and there was not the slightest doubt that in the person of Dr. Mellor they had one of these exceptional men who was capable of leading and tackling the sort of research that was required.

The PRESIDENT of the Cleveland Institution of Engineers (J. H. Harrison, Esq.) responded in a suitable manner.

Dr. J. E. STEAD, F.R.S., proposed "The Visitors." Referring to the fact that some 20 years ago he had the honour of being asked to become The Ceramic Society's first President he made a special point to discover, if he could, whether manufacturers of bricks, etc., were in favour of having such a society. After interviewing a number of firms in the district he was assured that the Society was not wanted, and that it would hardly be likely to meet with the necessary support as it meant making public trade secrets and methods. It was owing to the persistency of Dr. Mellor that they had at last a Society properly organised, and which at the present time had a membership of about seven hundred.

In responding to this toast Mr. W. W. STORR remarked: I do not think that the appeal with regard to the Research Association is likely to fall on deaf ears, because, apart from the compliment that has been paid to Middlesbrough by this visit of The Ceramic Society, it is of great interest to us. Your interests in this matter are our interests; we are your customers, and we look to you to supply us with the best materials possible for our purpose, and any successful researches which you make must essentially be to our benefit. The firmest friendships are founded on a community of interests, and the firmer these friendships are established the better it will be for us.

In conclusion, the CHAIRMAN expressed a vote of thanks to the Cleveland Club and the Tees Conservancy Commissioners for the wonderful and successful way in which the local committee of management had arranged all matters of detail connected with that meeting, and he asked them all to drink to their health.

On Friday morning a Business Meeting was held. The minutes of the last meeting were read and confirmed. It was decided that the next meetings of the Society should be as follows:—Autumn, 1919, Stoke-on-Trent; Spring, 1920, London; Autumn, 1920, United States of America. The Third Report of the Committee on the Standardization of Methods of Testing was passed by the meeting.

The SECRETARY of the British Refractories Research Association (Mr. R. C. Rann) gave a brief explanation of the Association.

Mr. Rann said: At the Swansea Meeting of The Ceramic Society, held in October, 1918, a resolution was passed authorizing the Council of the Refractory Materials Section to take the necessary steps for the formation of a Refractories Research Association.

Owing to various causes it was not until early this year that it was possible to call a Council Meeting to deal with this subject. On the 4th February, however, a meeting was held in London under the Presidency of Sir William J. Jones.

The following gentlemen were present:—

Sir William J. Jones, K.B.E. in the Chair.
Mr. F. H. Brooke, Mr. Bernard Moore,
Mr. G. R. L. Chance, Mr. G. H. Timmis,
Dr. H. G. Colman, Major C. W. Thomas,
Mr. H. E. Mason, Mr. G. Wink Wight,
Dr. J. W. Mellor, D.Sc.

Sir Frank Heath, Secretary to the Department of Scientific and Industrial Research, was also present by special invitation.

It was unanimously decided that a Refractories Research Association should be formed in connection with the Scientific and Industrial Research Department. The advantage of this plan is that the Department will contribute towards the expenses of the Association for a period of five years a sum equal to that contributed by its members.

The following Sub-Committee was appointed to carry out the necessary details in connection with the organization of the Association:—

Sir William J. Jones, K.B.E., Ministry of Munitions, London.
Dr. J. W. Mellor, Central Laboratory, Stoke-on-Trent.
Mr. B. Moore, Central Laboratory, Stoke-on-Trent.
Major C. W. Thomas, E. J. & J. Pearson, Ltd., Stourbridge.
Mr. G. Wink Wight, Jas. Dougall & Sons, Ltd., Bonnybridge.
Mr. Job Holland, Pickford, Holland & Co., Ltd., Sheffield.
Mr. T. Ellis, Penwyllt Dinas Silica Brick Co., Ltd., Neath.
Mr. H. J. C. Johnston, Leeds Fireclay Co., Ltd., Leeds.
Mr. H. E. Mason, Adam Mason & Sons, Ltd., Horwich.
Mr. C. P. Williams, John Lysaght, Ltd., Scunthorpe.
Mr. R. C. Rann, Secretary, London.

It was decided that the office of the Association should be in London, and Mr. R. C. Rann was appointed Secretary.

The Committee has held several meetings and Memorandum and Articles of Association have been drawn up. The Association can be registered and start working when this present report is approved by the Ceramic Society.

The essential features of the Association are as follows, it being borne in mind that it is entirely and altogether a Research Association and not a Trading Company.

1. It will be registered under the Companies Act as a Company not having a capital divided into share but limited by guarantee to a sum not exceeding Five Pounds per member towards liquidation expenses in the event of it being wound up during the period of membership or within one year afterwards. Outside of this the only liability of members will be for annual subscriptions. These subscriptions will have to be for a period of five years from the date of joining the Association, in order to secure the grant from the Department of Scientific and Industrial Research, which has been before referred to.

2. Members will consist of firms and companies engaged in the business of manufacturing, using and marketing Refractory Materials and Products.

3. The Association will be managed by a Council elected annually by the members. It is proposed that this Council shall represent every branch of the industry, and, so far as possible, every locality in which it is carried on.

4. Dr. J. W. Mellor of Stoke-on-Trent has accepted the position of Technical Director of the research work of the Association.

5. A good deal of consideration has been given to the question as to the best method of assessing subscriptions of members. Several methods have been suggested, based upon either output, capital, sales, wages, etc., etc. It is believed by the Committee that all of these are more or less open for objection. The Committee feel that the best method of raising funds is by means of a voluntary subscription from the members, with a minimum of five guineas per year, and ranging from that sum to 50 guineas per

year. It is understood that these subscriptions must be for a period of five years. It is estimated that the expenses of the Association will be in the neighbourhood of £6,000 per annum, half of which will be contributed by the Department of Scientific and Industrial Research, leaving an amount of £3,000 to be found by members of the Association. Subscriptions have already been promised from a few members amounting to over 500 guineas per annum for five years.

6. The Association will aim at the fullest degree of co-operation with similar Research Associations in other industries, particularly those closely allied.

7. The results of its work will be its sole property and be held in trust for the benefit of its members.

8. Members of the Association will be able to put technical questions concerning the industry, and to have them answered as fully as possible within the scope of the Association and Allied Research Associations.

9. Members will also have the right to recommend specific subjects for research to the Council. If the Council consider the subject of sufficient importance to the industry, research work will be undertaken and carried out at the cost of the Association, results being available to all members.

10. Members will also have the right to the use of any patents or secret processes resulting from the research work carried out by the Association on nominal terms of payment as compared with firms and companies who are not members.

11. It will be realised that no firm or company outside the Association will have any of these privileges or rights.

Programme of Research.

A preliminary programme of research work of the Association has been drawn up and is as follows:—

1. Requirements and resources, both home and foreign, of all kinds of refractories:
   - (*a*) Fireclays.
   - (*b*) Silica.
   - (*c*) Magnesite.

(*d*) Dolomite.
(*e*) Bauxite.
(*f*) Chromite.
(*g*) Zirconia.
(*h*) Graphite.
(*i*) Special materials such as carborundum, alundum, etc., etc.

2. Properties and qualities of refractories:
   (*a*) Physical.
   (*b*) Chemical.
   (*c*) Mechanical.

3. Preparation of refractories for service conditions in various industries, so as to secure uniformity of manufacture and quality.

4. Particular types of refractories most suitable for use in the following industries:
   (*a*) Iron and Steel.
   (*b*) Non-ferrous metals.
   (*c*) Coke ovens.
   (*d*) Gas works.
   (*e*) Chemical works.
   (*f*) Glass works.
   (*g*) Potteries.

So as to bring about utilization of higher temperatures and economies in fuel consumption.

The last is by far the most important branch. We have at our disposal sufficient knowledge of the general character of clays and raw materials for refractories to justify working on a big scale in industrial furnaces of most types in different centres. We may have to revise our knowledge on various points and clear them up, but this can be done side by side with the other work. The Association should concentrate on the investigation of particular types of refractories most suitable for various furnaces working under actual service conditions. The most practical and economical plan for carrying this out will be:

(*a*) To arrange for refractories to be made to its specifications under the supervision of the Association and at its expense.

(*b*) To arrange for testing these under service conditions in various works in all parts of the country, also under the supervision and at the expense of the Association.

In line with this branch of work, and in view of the increasing difficulties with fuel and labour, it is important that the subject of kilns be taken in hand immediately.

The following resolution was passed:—"That this meeting approves of the proposed scheme of research of the British Refractories Research Association, and directs that immediate steps should be taken to put the scheme into active operation." The election of officers then took place.

The following were nominated by the local sections to represent the various centres:—

Yorkshire:—Mr. D. Thornton, Mr. A. Lumb, Mr. M. Barrett.

Stourbridge:—Mr. G. R. L. Chance, Mr. G. H. Timmis, Mr. G. V. Evers.

Scotland:—Mr. Wm. Douglas, Mr. Wm. Donald, Mr. J. Mitchell.

Sheffield and Lincolnshire:—Mr. Cosmo Johns, Mr. Cyrus Jones, Mr. J. Holland.

Lancashire, N. Wales and Derbyshire:—Mr. T. A. Acton, Mr. Wm. Fagan, Mr. H. E. Mason.

South Wales:—Mr. Thos. Ellis, Mr. A. Stephens, Mr. S. Jones.

On the proposal of Mr. Ridge, seconded by Mr. Atkinson, the nominations were confirmed.

The Council submitted the following for election as Vice-Presidents:—

Dr J. E. Stead, Dr. H. G. Colman, Prof. J. W. Cobb, Lt.-Col. C. W. Thomas, Mr. C. P. Williams, M.Sc., Mr. W. Hamilton, Mr. J. H. Whiteley, Mr. J. Dunnachie, Junr., Mr. F. H. Brooke, Mr. B. Moore, Sir W. J. Jones, Mr. A. Cliff, Mr. D. Sillars, Dr. A. McCance,

and the following as ordinary members:—

Mr. J. P. Leather, Mr. C. Wink Wight.

Mr. T. A. Acton proposed that the list be accepted, Mr. J. Audley seconded, and same was duly carried.

The Council of the Society suggested that Sir Wm. Jones be elected President. The suggestion met with great enthusiasm and was carried unanimously. Various nominations for membership of the Society were read. A vote of thanks was passed to the authors of papers; the authorities of the Literary and Philosophical Society, Middlesbrough; the Reception Committee; the Tees Conservancy Commissioners, and the proprietors of the works which were visited.

The following papers were communicated:—"Refractories for Glass Works Use," by W. J. Rees; and "Further Notes on Zinc Furnace Refractories," by J. A. Audley, B.Sc.; and the following were communicated by title: "Notes on the Manufacture of Silica Materials," by Dr. A. Bigot; and "The Glazing of Refractories," by Mr. J. C. Thomlinson, B.Sc.

During the afternoon a party of members, by invitation of the River Tees Conservancy Commissioners, inspected the River Tees and were entertained to Luncheon at the 5th Buoy Lighthouse. Other parties visited the works of Messrs. Bolckow, Vaughan & Co., Ltd.; Cargo Fleet Iron Co., Ltd.; Dorman, Long & Co., Ltd.; South Durham Steel & Iron Co., Ltd., and Skinningrove Iron Co., Ltd.

In the evening Dr. W. R. Ormandy lectured on "The Osmotic Purification of Clays, a Review," and brought a very successful meeting to a close.

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ABSTRACTS.

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Introduction.

THE following are abstracts from papers connected with the clay, refractories, and glass industries in the more important foreign journals as well as those of our own country. The abstracts are arranged roughly in thirteen classes. The groups are constantly overlapping, and, to avoid repetition, a copious index is appended. This will enable any reference to be quickly found. Most of the journals quoted are permanently filed so that the full papers may usually be consulted by members of the Society. Full translations of any of the foreign papers can be obtained at a small charge. As a rule the abstractor indicates the "subject title" of those articles which, in his opinion, contain either no original matter, or matter not suitable for abstraction.

These abstracts were made possible by a grant from the Joint Committee of Allied Pottery Manufacturers, and were compiled by Mr. J. A. AUDLEY, B Sc. (with the exception of a few initialled).

The following particulars respecting patents may be of use to members:—

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In ordering a copy of a patent, the number of the patent and year of the patent, the name of the patentee and the subject of the invention should be stated.

Titles of Journals Abstracted, with Abbreviations.

Amer. Jour. Sci...."American Journal of Science" (American)
Amer. Pot. Gaz. ..."American Pottery Gazette" (American)
Brick..."Brick and Clay Record" (American)
Brick Pot. Tr. J. ..."Brick and Pottery Trades Journal" (British)
Brit. Claywr. ..."British Clayworker" (British)
Bull. Imp. Inst. ..."Bulletin Imperial Institute" (British)
Cement Eng. News. ..... "Cement and Engineering News" (American)
Cer. ..."La Céramique" (French)
Chem. Appar...."Chemische Apparatur" (German)
Chim. Ind. ..."Chimie et Industrie" (French)
Claywr...."Clayworker" (American)
Deut. Töp. Zieg. Ztg...."Deutsche Töpfer- und Ziegler- Zeitung" (German)
Diamant ..."Diamant Glas-Industrie Zeitung" (German)
Feuerung..."Feuerungstechnik" (German)
Glash..."Die Glashütte" (German)
Glas-Ind. ..... "Die Glas-Industrie" (German)
Ind. Chim...."L'Industrie Chimique" (French)
J. Soc. Chem. Ind..."Journal of the Society of Chemical Industry" (British)
J. Soc. Glass Tech. .."Journal of the Society of Glass Technology (British)
Kalk. Schm.-Ztg. ..... "Kalk-, Gips- und Schamotte-Zeitung" (German)
Ker. Rund. ..."Keramische Rundschau" (German)
Silik.-Zeits. ..."Silikat-Zeitschrift" (German)
Min. Min...."Mines and Minerals" (American)
Monit. Cer. Ver......"Moniteur de la Céramique et la Verriere" (French)
Pat. J...."The Illustrated Official Journal (Patents)" (British)
Pot. Gaz. ..."Pottery Gazette" (British)
Pot. Glass..."Pottery and Glass" (American)
Pot. Glass Rec...."Pottery and Glass Record" (British)
Prod. Chim. ..."La Revue des Produits Chimiques" (French)
Quarry ..."Quarry" (British)
Sprech. ..."Sprechsaal" (German)
Tonind. Ztg...."Tonindustrie-Zeitung" (German)
Tonwaar. Ind. ..."Tonwaaren Industrie" (German)
Tonwar. Ofen. Ztg. ....."Tonwaren-Ofen und Töpfer Zeitung" (German)
Tonwar. Fab. ..."Tonwarenfabrikant" (German)
TRANS. ..."Transactions of The Ceramic Society" (British)
Trans. Amer. Cer. Soc..."Transactions of the American Ceramic Society" (American)
Zeits angew. Chem. ....."Zeitschrift für angewandte Chemie" (German)
Zentr. Zieg......"Zentralblatt für Glas-, Porzellan-, und Ziegelindustrie" (Austrian)

Also a number of other Journals not devoted exclusively to Pottery and Clays.

There is a difficulty in procuring some Continental Journals; and some have ceased publication while the war is on.

*** The first number represents the number of the volume, the last the year of publication, and intermediate numbers the page or pages where the subject is discussed.

Abstracts.

I.—RAW MATERIALS.

KAOLIN FORMATION.—Lochte (*Tonind. Ztg.*, 41, 52, 1917). According to Fausto Sestini (*Landw. Versuchsstat.*, 54, 147, 1900) plants by their roots exercise an important influence on the decomposition of felspar. Sestini found that a granite sand in Elba, freed by sieving, washing, and brushing from adhering particles of soil, consisted merely of quartz, mica and felspar. About 13 per cent. of the sand had a grain size of $\frac{1}{4}$ to 1 mm., 23 per cent. was 1 to 5 mm., and only 3 per cent. was in larger grains. Plants in this sand provided with sufficient pure water were all starved for lack of nourishment, so with 1 kg. of an air-dried sand 100 g. calcium carbonate, 10 g. calcium phosphate, and 30 g. calcium sulphate was used for fertilizing. After growing certain plants from seeds in this prepared soil for nearly 20 weeks, it was found by careful treatment that a quantity of fine earth had been formed, its chemical composition proving it to consist of half clay. Comparison trials with the same sand, the same watering, but without plant growth, and with plant growth but without fertilizing with carbonates produced no noticeable disintegration of the same (*Jahresbericht über die Fortschritte auf dem Gesamtgebiete der Agrikultur-Chemie*, 1900, pp. 45 and 46). Vegetation promotes decomposition of felspar, and the formation and origin of clay in the ground is therefore not to be ascribed to merely physico-chemical actions.

ZIRCONIA AS A REFRACTORY.—A. Spengel (*Tonind. Ztg.*, 41, 175, 1917). Small crucibles, tubes, etc., of zirconia, have been used for some time in carbon-tube resistance furnaces to withstand temperatures over 2,000° C. For admixture with zirconia are suitable, at 2,000° C., 1 per cent. alumina, at 2,200° about 1 per cent. thoria, at 2,400° C. 1 to 3 per cent. magnesia. The production of zirconia vessels demands skill, and not more than 9 to 10 per cent. of water is needed for producing the correct plastic mass, and 1 per cent. starch may be used if desired. After hand-pressing, the objects are carefully dried at 120° to 140° C. After drying they are preheated to 1,500° C. on coarse zirconia powder. The final heating is carried out in a Ruff carbon-tube resistance furnace at 2,000°, 2,200°, 2,400° with a vacuum of 30 mm. mercury. The firing up takes about an hour, and the highest temperature is also maintained for an hour. The power required is 8 to 12 KW. References are made to *Zeits. anorg. Chem.*, 1914, p. 198, 1916, pp. 73—112; *Zeits. angew. Chem.*, 1915, p. 116; Ruff and Lauschke: *Sprech.*, 1916, 270, 275, 281, 289, 297, 305, 313, 322, 329, 337.

STONEWARE CLAYS.—(*Tonind. Ztg.*, 41, 374, 1917). A note on the general character of such clays. The composition of German stoneware clays after firing fluctuates within the limits 60 to 75 per cent. silica, 18 to 30 alumina, 1 to 5 iron oxide, 0 to 3 lime, 0·2 to 2 magnesia, 1·5 to 4 alkalies.

KIESELGUHR.—H. (*Tonind. Ztg.*, 41, 631, 1917). A description of infusorial earth from the island Mors and Limfjord. Analyses are given.

REFRACTORY MATERIALS IN CANADA.—N. B. Davis (*Trans. Can. Min. Inst.*, 20, 226, 1917). Deposits containing material suitable for refractory purposes are scarce in Canada, and hitherto refractories have had to be imported. Fireclays are found locally in the Maritime Provinces, but they are only semi-refractory material of Carboniferous age softening at cones 15—25, and of Cretaceous age at cone 30. A promising kaolin deposit is found at

St. Remi, Quebec, while a fireclay in Michipicoten, Ontario, has as softening point cone 26. Clays suitable for the manufacture of vitrified ware are found in Saskatchewan. A hard fireclay, softening at cones 28—32, 15 feet thick, and of Tertiary age, occurs along with easily vitrifying shales at Sumas Mt., B.C., and will probably prove a useful deposit. Chromite is exported in considerable quantities from Quebec, where it occurs disseminated through serpentine rocks.

Trials have been made of several siliceous rocks, with a view to the production of silica bricks. Quartzites give much better results than either quartz from pegmatites, etc., or sandstones; for example, a quartzite containing 11 per cent. kaolin gave a product which after burning, first at cone 9 and then at cone 18, had a softening point above cone 27. Good bricks could not be obtained from the Potsdam sandstone owing to the high proportion of fine material and high iron content.

For basic materials, magnesite, dolomite, etc., see Crook (*Trans. Cer. Soc.*, 18, 67, 1918), Wilson (*ibid.*, 17, Abs., 64, 1918). A.S.

THE DEVELOPMENT OF CANADIAN MAGNESITE.—H. J. Roast (*Trans. Can. Min. Inst.*, 20, 237, 1917). A summary of the properties and uses of Canadian magnesite. It is stated that the Grenville material can be dead-burned only above 1,700° C., and that the softening point is above 1,800° C. A lime content, up to 16 per cent., does not increase the tendency of the dead-burned material to absorb water, even after fine grinding and prolonged exposure to moist air. Cf. Wilson (*Trans. Cer. Soc.*, 17, Abs., 64, 1918), Crook (*ibid.*, 18, 67, 1918). A.S.

POTASH, ITS PRESENT AND OTHER POSSIBLE SOURCES.—C. W. Drury (*Trans. Can. Min. Inst.*, 20, 292, 1917). From a discussion of the many sources of potash which have been suggested as alternative or complementary to the German supplies, it is concluded that it is impossible to extract potash economically from silicates, though it may be possible to utilise those processes which merely aim at the production of a material containing water-soluble potash. A.S.

BAUXITE DEPOSITS AND THE PRODUCTION OF ALUMINIUM.—(*Engineering*, 106, 163, 191, 218, 1918). Hungarian bauxite deposits, chiefly of the Jurassic period, and consisting of irregular knolls, occur in the southern portion of Bihárhegyzég, in the Galbina Valley, and in the districts of Petrosz and Sykerisora. In 1905 Szadeczky demonstrated the existence of seven substantial layers, and three years later the number of known layers had increased to 18, the contents being estimated at 1,000,000 tons. Bauxite is also found in the northern part of Bihárhegyzég, at Jádvölgy, in Jurassic limestone, there being seven layers with a content of 350,000 tons. Similar deposits are found at Bihármegyei Királyerdö, variously estimated at 6,000,000 to 18,000,000 tons. Other important deposits occur in the Possieior Hodisanulu district, in the southern part of Királyerdö, estimated at 7,200 000. Bauxite is also found in the Gracac district, Croatia, also in limestone or on limestone, the quantity being estimated at 1,000,000 tons. Bauxite deposits are located in Dalmatia, in the Southern Velebit Mountains, and in Bosnia, in the Studenovzelo district at Mostar. Bauxite deposits in limestone mountains are found in Serbia, in the neighbourhood of Badujévács, in the Kragujévácz district.

In Austria bauxite deposits are met with in Krain, in the Wocheim-Feistritz district, and in Styria and the Tyrol. In Germany, in the Grand Duchy of Hesse, in and about the Vogelsberg Mountains, bauxite occurs in small lumps up to the size of a man's head. In Italy bauxite is found in the Apennines at Abruzzo and Ferra di Livoro. In Southern France it occurs in the departments of Var and Bouches du Rhône. In Ireland it occurs about Belfast. Bauxite is found in India and in tropical countries generally. It also occurs, together with limestone and dolomite of the Silurian period, in the United States, in the districts of the River Alamba, in Georgia, where the bauxite takes very irregular shapes.

The annexed table contains particulars of the chemical composition of various kinds of bauxite, good and poor. They are the outcome of some 150 analyses undertaken by **M. Bélo Horváth**

ANALYSES OF BAUXITE FROM VARIOUS SOURCES.

	District	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	Loss on ignition	Other substances	Total
		pr. ct	pr. ct.	pr. cnt.	pr. cnt.	pr. cnt.	per cent.	pr. cnt.
	Bihárhegyzég (Hungary)							
1	East of Vaskóh ...	1·52	3·10	53·20	27·66	14·39	CaO, 0·20 ; MgO, trace	100·07
2	Peatra Galbina ...	1·52	1·95	58·26	30·22	8·09	MgO, 0·09 ...	100·13
3	Right of the Izvor ...	2·84	3·15	55·91	28·09	10·42	CaO, 0·10 ...	100·51
4	Falza Arzs-tetö ...	6·69	3·10	58·70	19·23	11·80	CaO. 0·80 ...	100·32
	Királyerdö—							
5	Rév ...	0·80	3·20	53·70	29·70	—	——	87·40
6	Beharrósa ...	1·62	1·15	60·83	25·82	11·31	——	100·73
7	Vércsorog ...	1·67	1·05	59·65	24·66	14·09	——	101·12
8	Cucuhegi Tizfaluh	12·38	3·95	58·74	7·84	16·31	CaO, 0·32, ; MgO, 0·11	99·65
	Croatia—							
9	Rudopolje ...	6·30	—	66·02	14·82	12·70	——	99·84
10	Grgienbrieg ...	10·29	—	50·61	26·89	11·29	——	99·08
11	Mazin ...	33·0	traces	38·37	19.85	8·11	CaO, 0·77 ...	100·10
	Dalmatia—							
12	Moséc ..	0·87	—	59·27	24·36	15·93	——	100·43
13	Ilvar ...	30·47	—	29·05	16·24	17·14	CaO, 6·79 ; MgO, trace	99·69
	Bosnia—							
14	Studenovrelo ...	0·37	8·51	55·37	21·76	13·45	ZrO_2, 0·45 ...	99·91
	Austria—							
15	Sannthal ...	6·32	0·91	64·05	15·93	13 28	——	100·49
16	Feistritz ...	13·60	—	57·25	0·97	24·38	CaO, 1·80 ; P_2O_5, 1·40	99·40
	Germany—							
17	Garbenteich ..	1·10	3·20	50·92	15·70	28 60	CaO, 0·80 ; MgO, 0·16	100·58
18	Firnewald ...	4·92	2·80	53·10	10·62	27·80	CaO, 2·62 ; MgO, traces	99·86
	France—							
19	Thovonet (Var) ...	0·30	3·40	69·30	12·90	14·10	——	100·00
20	Allanch (Bouches-du-Rhône) ...	4·80	3·20	55·40	24·80	11·60	——	100·00
	Ireland—							
21	Belfast, Co. Antrim	6·01	—	61·89	1·96	27·82	——	97·98
22		15·05	—	43·44	2·11	35·70	——	96 30
	North America—							
23	Georgia ...	6·62	1·05	64·91	0·28	33·53	——	100·39
24	Jacksonville,	10·25	2·53	41·00	25·25	21·08	P_2O_5, traces ...	100·11
25	Alabama	21·08	2·52	48·92	2·19	23·86	P_2O_5, traces ...	98·57

ANALYSES—Nos. 1, 2. 6, 7, 8 and 15, were by B. Horváth ; Nos. 3, 4, 21 and 22, by E. Apor ; No. 5 by Schelle ; Nos. 9, 11, 12 and 14, by Tucan ; Nos. 10 and 13, by Krmpotic ; No. 16 by Henatsch ; Nos. 17 and 18, by Liebreich ; No. 19 by Augé ; No. 20 by Deville ; No. 23 by Watson; and Nos. 24 and 25 by Hillebrand.

The bauxite from the Hungarian Bihar Committate is of a fairly satisfactory quality, and with the present methods aluminium can be extracted with remunerative results, cheap water power being available. The Bihar bauxite, however, contains, in some cases at least silica, which is detrimental to the production of aluminium, as even 2 per cent. makes the aluminium brittle. In addition, silica combined with sodium, enters into combination with aluminium in the form of a complex sodium-aluminium silicate (probably the orthosilicate, $NaAlSiO_4$), which will not dissolve and makes part of the aluminium useless. The percentage of silica in certain varieties of bauxite averages 1·36, that of alumina 30·76. The silica will bind 0·61 per cent. of alumina, so that only 1·98 per cent. of the alumina will be lost in this way, and those qualities of bauxite are well suited for aluminium production.

Besides bauxite proper ($Al_2O_3 2H_2O$) there are the less frequently found diaspore ($Al_2O_3H_2O$) and gibbsite ($Al_2O_3 3H_2O$).

The principal constituents of bauxite are alumina, ferric oxide, silica, and water. Titanic acid (TiO_2) and other substances are also frequently present. The colour of bauxite is mostly a reddish-brown. but may vary considerably according to composition.

Dr. B. Horváth gives as the average values of 150 different samples of bauxite from different parts of the world as follows:—

Substances always present.	Per cent.
Al_2O_3	9·05 to 76·90
Fe_2O_3	0·10 to 58·02
SiO_2	0·30 to 58·03
H_2O	5·85 to 35·70
Substances sometimes present.	
TiO_2	0 to 12·21
ZrO_2	0 to 2·71
CaO	0 to 8·24
MgO	0 to 1·32
K_2O	0 to 0·32
Na_2O	0 to 1·36
P_2O_5	0 to 1·50
SO_3	0 to 0·49
CO_2	0 to 6·26
Mn	0 to traces
Li	0 to traces
V	0 to traces

To obtain pure alumina the raw material must first be transformed into soluble sodium aluminate, and at the same time the impurities must be kept insoluble. In the Deville-Pechiney (dry) process, a suitable mixture of finely-ground bauxite and soda is roasted at about 1,100° C., the roasting lasting 4 hours. The greyish-brown product is lixiviated with boiling water to dissolve the sodium aluminate (with a little sodium silicate). The lye is passed through filter-presses, and is then heated in an autoclave to about 160° C. under a pressure of 85 lb. per square inch, when the silica (about 3 per cent.) is precipitated as an insoluble sodium aluminium silicate. Carbon dioxide is blown into the heated lye (which after settling does not contain above 0·3 part SiO_2 for 100 parts Al_2O_3) and aluminium hydroxide is easily precipitated as a thick grainy substance. The process yields very good results both as regards quantity and the purity of the product. The accumulation of the by-products, lime (from limestone used for getting CO_2) and soda (left in solution after precipitation of aluminium hydroxide), which may be mixed to produce caustic soda, is often inconvenient. To avoid by-products the Bayer (wet) process may be used, the finely-ground bauxite being mixed with concentrated soda lye, and the mixture heated (for about 8 hours) in autoclaves with steam jackets, under a pressure of seven atmospheres The alumina dissolves in the soda lye, the Fe_2O_3 and TiO_2 remaining undissolved. The silica present at the same time forms an insoluble sodium aluminium silicate, no silica being left in the lye. It is estimated that 85 to 88 per cent. of the alumina in the bauxite is dissolved in this process. The aluminium hydroxide resulting from both processes contains about 50 per cent. of water, partly combined and partly as moisture. To obtain anhydrous alumina the product is calcined in a rotary furnace, the maximum temperature at the delivery end being about 1,350° to 1,400° C. Several modifications of the two main processes are briefly alluded to.

White bauxite, which contains as much as 25 per cent. silica, but only 5 per cent. of iron oxide, is treated differently from red bauxite. It is finely ground and slightly heated to make it more porous. Warm sulphuric acid of specific gravity 1·25 is then carefully added to the bauxite, the result being aluminium sulphate. Steam and water are added until the sp gr. becomes 1·2. The iron is removed, either before or after dissolving, and the solution of aluminium sulphate is evaporated, and the residual sulphate is calcined in carbonating furnaces, the escaping sulphur trioxide and dioxide being converted into sulphuric acid. The aluminate remains, and can be used direct for the production of aluminium.

In America, Hall introduced a more direct method for purifying bauxite, by calcining in electric furnaces the bauxite mixed with 10 to 15 per cent. of coal, the chief product being a very fusible alloy of iron, silicon, titanium, and aluminium, which is tapped off. This treatment is understood to be applicable to aluminates and to aluminium silicates, although the purified aluminate is not supposed to be as pure as with the chemical processes, nor will it so easily dissolve in the cryolite bath. Cowles and Kayser have also used the electric furnace for the production of pure aluminate.

At Sevaren, N.J., a tunnel furnace is used for heating briquettes made from a mixture of kaolin, felspar, or aluminate with sodium chloride (in the proportion of 19 pure Al to 23·4 salt), 15 per cent. charcoal being added to accelerate the reaction. The product is a sodium alumino-silicate, $2SiO_2.Al_2O_3.2Na_2O$, with hydrochloric acid. The former is treated with lime in a rotary furnace, when calcium silicate is formed along with sodium aluminate ($2Na_2O.Al_2O_3$). Excess of lime would form an insoluble calcium aluminate, and deficiency of lime would leave part of the insoluble sodium alumino-silicate. The aluminate is decomposed by soda lye as usual. The calcium silicate could be used in the cement or glass industry.

Dr. Serpek, before the war, was in a fair way to combine the manufacture of aluminium with that of ammonia. Serpek and Badin worked with large rotary electric furnaces, where the aluminate was treated with coal and nitrogen gas at 1,600° to 1,800° C. By using catalysts such as iron and hydrogen, the reaction can commence at 1,300° C. The furnace was lined with aluminium nitride: $Al_2O_3+3C+N_2=2AlN+3CO$. This aluminium nitride, with water under pressure in autoclaves, yields alumina and ammonia: $2AlN+6H_2O=2NH_3+Al_2O_33H_2O$.

After distilling off the ammonia the alumina can be used again in the furnace. If alumina is wanted for aluminium production the aluminium nitride is placed in soda lye, and the ammonia will escape in the course of 2 to 2½ hours at 2 atmospheres pressure. The further treatment of the aluminate takes place according to the Bayer method, but the treatment in the autoclaves is somewhat simplified.

Dr. Serpek states that only 2 atmospheres are required instead of 8 atmospheres, the process being shorter and the concentration only 20° Baumé instead of 40°. This Bayer nitride process is stated to cost only 63 frans per ton of pure aluminate, instead of 126 francs by the Bayer process, exclusive of the cost of bauxite. In addition, ½ ton of nitrogen is fixed per kilowatt year, corresponding to 2 tons of aluminate. Ferro-aluminium has also proved itself able to fix nitrogen endothermically.

Natural cryolite is found at Ivigtut, in Greenland, and also at Minsk, in the Urals, its chief impurities being quartz, iron pyrites, carbonate of iron, and galena. As supplied by the Oresund Chemical Works, Copenhagen, it contains some 50 per cent. fluorine, 12 to 13 per cent. alumina, with only ¼ to ½ per cent. silica and $^1/_{60}$ per cent. iron. Cryolite melts at about 1,000° C., and at a red heat loses up to 1 per cent. of water. At white heat the sodium and fluorine pass off, and alumina remains in the shape of hexagonal plates. Artificial cryolite contains more fluorine (because less impurity is present), and it is therefore better to use, but it also smokes more.

Cryolite is used for dissolving the aluminate, when undergoing electrolysis in the electric furnace to produce aluminium.

Electrodes have to be nearly pure, and they should not contain more than 1 per cent. of ash. Ordinary coal or coke cannot be used in making them, because even the purest anthracite gives electrodes with over two per cent. of ash, of which at least one-third is silica. Natural graphite and coking coal are also not pure enough, and graphite is rather expensive. For purposes of electrolysis the current density should be 0·6 sq. cm. per ampere, or 0·9 to 1 sq. cm. per ampere, and even a lower current density is used. Retort carbon is used, but it generally contains some silica, and it is therefore preferably used as an addition. Acheson's graphite is very pure, but too expenisve for use in Europe. Petroleum coke is therefore generally used, though also expensive, its ash amounting to only 0·1 to 0·4 per cent., and rarely above 0·5 per cent.

The petroleum coke generally contains volatile substances (sometimes up to 15 per cent.), which must first be driven out by a red heat, in order to get good firm electrodes.

After this heating process the coke is finely ground, generally along with electrode remnants, and sometimes with retort graphite added. The finely-ground coke is mixed with about 20 per cent. of tar, some factories using less tar and one-third pitch. A little soot is supposed to make the electrodes firm, but the soot is often impure. Coal-tar pitch, which at most contains 1 to 2 per cent. of ash, is used. Blast-furnace pitch, which contains 20 per cent. of ash, is useless for this purpose. The ground material is mixed in kneading machines heated with steam. After a preliminary moulding, the substance goes to the electrode press, in which it is exposed to as much as 500 atmospheres pressure. An electrode press is illustrated. When the electrodes have been pressed and moulded, they are baked in a kiln, being exposed to a temperature above 1,400° C., and losing about 10 per cent. of their weight. In the Mendheim tunnel furnaces the electrodes are burned at 1,350° C., which is sufficient for electrodes for aluminium furnaces with a bath working at only 1,000° C. The furnace mostly in use is probably that of F. Meisser, consisting of 16 chambers on each side of a gas conduit. A more recent Mendheim annular chamber furnace is also used.

In the aluminium furnace the cryolite melts at 1,000° C., the melting temperature being reduced by addition of a little alumina (5 per cent. of this giving the minimum melting temperature). Addition of aluminium fluoride lowers the melting temperature further, and also facilitates solution of the aluminate. Aluminium carbide, Al_4C_3, which is liable to be formed when the bath contains 20 to 30 per cent. of alumina, or if the furnace be overheated, is yellow, and crystallizes hexagonally; it is reduced very slowly to alumina and methane gas when treated with water at ordinary temperature. (Hence Moissan suggested that the escape of methane—that is, marsh gas—from the earth is due to aluminium carbide in its interior). The treatment of aluminium furnaces is described in considerable detail, including the bath, electrodes, etc. References to the chief aluminium factories of the world are also given.

THE TERNARY SYSTEM, $MgO.Al_2O_3.SiO_2$.—G. A. Rankin and H. E. Merwin (*Amer. Jour. Sci.*, 45, 301, 1918). The freezing point surface has been examined thermally and the equilibrium relations of the various compounds determined. The substances found in the three binary systems are all stable in the ternary system in contact with the melt, while one ternary compound occurs. The former comprise, besides the simple oxides, forsterite (Mg_2SiO_4), clinoenstatite ($MgSiO_3$), sillimanite (Al_2SiO_5) and spinel ($MgAl_2O_4$), while the latter is apparently an anhydrous form of cordierite, of composition $Mg_2Al_4Si_5O_{18}$. The ternary compound exists in two forms with a variable inversion point ranging from 925—1,150, while the high temperature form dissociates below its melting point. Numerous data for the melting temperatures of the compounds and various mixtures are given, as well as isothermal diagrams of the freezing point surface. The properties of the ternary compound, especially the α or high temperature stable form, closely resemble those of natural cordierite; the latter also dissociates on heating. A.S.

CRYSTALLIZED MONTMORILLONITE.—H. Leitmeier (*Zeits. Kryst. Min.*, 55, 353, 1916). A yellow clay mineral from the Progress Mine, (copper, lead, and silver) in the Hermanli district, Zogora, Bulgaria, was a perfectly isotropic gel when received, but after being kept for three years it showed a feeble birefringence, indicating that it had become crystalline throughout most of its substance. This is supposed to have been brought about by increase in size of the grain of the material. The analysis corresponds to the formula $Al_2Si_4O_{11}.6H_2O$.

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	H_2O	Total
50·14	19·74	4·14	1·26	2·28	22·61	100·17

II.—THE PHYSICAL, CHEMICAL, AND OTHER PROPERTIES OF RAW AND FINISHED PRODUCTS. TESTING.

FORMATION OF ZINC FERRATE [AND ALUMINATE].—E. H. Hamilton, G. Murray and D. McIntosh (*Trans. Can. Min. Inst.*, 20, 168, 1917). Zinc oxide and ferric oxide, ground together to give an intimate mixture, react to form zinc ferrate, $ZnFe_2O_4$, if subjected to a sufficiently high temperature, the yield varying with temperature and duration of heating. The reaction is complete after heating for 1 hour at 1,600° F., or 3 hours at 1,400° F.; while a 70 per cent. yield is obtained by heating at 1,200° F. for 4 hours. At 1,100° F. no reaction occurred in 8 hours. Similarly zinc oxide and alumina react to form zinc aluminate at a temperature of 1,200° F., but no combination between zinc oxide and fireclay could be detected at 1,500° F. A.S.

THE OCCURRENCE AND TESTING OF FOUNDRY MOULDING SANDS.—L. H. Cole (*Trans. Can. Min. Inst.*, 20, 265, 1917). The moulding sands used in foundry practice may be divided into three types: natural, prepared, synthetic. The first type comprises two classes of deposit: (*a*) flood plain deposits consisting of silica grains coated with a binding clay material, and (*b*) ancient beach sands which have been rewashed and in many cases redeposited. The second type comprises those sands obtained by crushing friable sandstones, decomposed granite, etc., while the third includes those made by mixing crushed quartz or sand with clay.

In place of the present empirical methods of selection, a number of laboratory tests are proposed. These include texture, refractoriness, bonding power, permeability, durability and micro-examination.

The *texture* is determined by passing a sample, initially weighing 100 grms., through a series of Tyler standard screens and weighing the amount retained on each screen. From this the average fineness is calculated by multiplying the weight of the material, retained by each screen, by the mesh of the next coarser screen, totalling the results so obtained and dividing by 100. The *refractory test* is carried out in the usual manner.

Bonding power cannot be very accurately determined, but the method used is the one devised by the Bureau of Standards. A quantity of sand is moulded with water into a test-bar 12 in. long by 1 in. in cross section and laid on a weighed glass plate. The whole is again weighed in order to get the weight of the bar. The bar is then pushed lengthwise over the edge of the glass plate until pieces break off. The average length of overhang at the breaking moment is measured and the transverse strength calculated from the formula $S=\frac{WL^2}{4\times 453{\cdot}6}$ where $S=$ transverse strength, W weight of bar, and L length of overhang in inches. The process is repeated with different amounts of water and the average of all the results calculated.

Permeability is determined by passing ordinary illuminating gas at a definite pressure through a cylinder of the sand and igniting it as soon as it reaches the top. The time elapsing between the turning on of the gas and the ignition is a measure of the permeability.

Durability tests are carried out under working conditions by determining the number of castings that can be made using one sample of the sand under test. Micro-examination of the same sample is made before use and after each burning, to determine if any sintering of the grains has occurred.

The results of the testing of a particular sand are appended. A.S.

TESTING BRICKS.—W. Walter (*Tonind. Ztg.*, 41, 92, 1917). An account of a method of testing taken from a book by Justi dated 1765, "Schauplatz der Künste und Handwerke."

GRAIN-COMPOSITION OF MORTAR SANDS.—S. Kiehne (*Tonind. Ztg.*, 41, 181, 187, 1917). The author in his concluding remarks (after a mathematical discussion of the subject) states that in mixing three kinds of balls the following two limiting cases are to be distinguished. In one the kinds of balls are piled on one another cubically in separate layers, in which case the interspaces amount to 47·6 per cent., or they lie so as to form the densest mixture, when the interspaces amount to 21·6 per cent. The mean is 34·6 per cent.

In practice, it follows that the grain composition of a sand should in size and number approach as near as possible to the ideal form as sketched in the paper.

In actual calculations a direct contact of the individual grain is not assumed, but a flux of about 15 per cent. is supposed to be present, so that every sand grain will be covered with a thin skin of cement. The finest grades of sand grains thereby gain in importance. By use of the ideal form of the sand with a cement output of 90 per cent. a mortar of density 1 was obtained with the mixture $1 : 0{\cdot}9/0{\cdot}216 = 1 : 4{\cdot}16$, and a mortar of density 1·15 with the mixture $1 : 0{\cdot}9/1{\cdot}15 \times 0{\cdot}216 = 1 : 3{\cdot}63$.

UNIFORMITY OF FIRECLAYS.—T. Neizer and F. Bochring (*Tonind. Ztg.*, 41, 429, 462, 1917). By means of analyses of four samples taken at distances of about 5 yards, it is shown that the silica varied pretty regularly from 46·35 to 52·20 per cent., the alumina irregularly between 33·76 and 36·00, ferric oxide irregularly between 2·01 and 3·11, lime nearly regularly from 0·50 to 0·30, magnesia irregularly from 0·63 to 0·15, potash irregularly between 2·73 and 0·27, and loss on ignition pretty regularly from 12·65 to 9·60 per cent. On p. 462, F. Bochring gives two concordant analyses, one of dark-coloured clay, the other light-coloured.

CONTRACTION OF TILE BODIES.—G. Heinstein (*Tonind. Ztg.*, 41, 353, 1917). An account of an investigation of the contraction (both drying and firing) of Westerwald clay, alone and when mixed with an equal weight of grog (coarse or fine), quartz (coarse or fine), felspar or chalk; the firing being carried to cone 08 and to cone 5 respectively. Some tests were also made in which the grog used was half coarse and half fine, and others in which grog and chalk, or quartz and chalk, were used.

The general results indicate that in order to increase the drying contraction (1) the water content of the mass should be increased, (2) the non-plastic contents should be reduced (grog, quartz, chalk, or felspar), or the clay should be substituted by another which contracts more, (3) the non-plastic material should be ground more finely. To increase the firing contraction (1) the sand, grog or felspar should be reduced at the expense of the clay, or the clay should be substituted by one which contracts more, (2) the sand should be substituted by grog or felspar (the difference in the influence of these two being small at the temperature for the tiles in question), (3) the non-plastic material should be ground more finely. To reduce contraction the opposite course is to be taken.

By increasing the lime content, the firing contraction can be increased or decreased, according to the firing temperature, mixing proportions, the nature and fineness of the raw materials, and whether the lime is used wholly or only partly as carbonate. In general with increase of chalk the firing contraction is reduced with weakly burned tiled bodies but increased with strongly burned bodies.

FINE CRACKS IN MOSAIC TILES.—H. Kampff (*Tonind. Ztg.*, 41, 436, 1917). Though suspected to be due to difference in contraction between the main body and the covering body, these were found to give the same contraction in separate pieces fired in the same saggar. Eventually the author ascribes the result to addition of china clay and quartz to improve the white colour. This addition resulted in production of the fine cracks at an early stage, though the subsequent course of the expansion made them close up again, and they only became visible on wetting the surface.

MAKING FAT CLAYS LEANER.—B. Kosmann (*Tonind. Ztg.*, 41, 476, 1917). A discussion of Dr. North's German patent 295,719, which claims to get rid of excessive plasticity of ordinary fat clays by simply heating them to remove the fat they contain.

CONDUCTIVITY OF CLAY MATERIALS FOR HEAT.—F. Tschaplowitz (*Tonind. Ztg.*, 41, 509, 1917). A brief account of a method for determining the conductivity, with comparative values obtained for grog, brick, loam, etc.

REFRACTORY BRICKS FOR CARBIDE FURNACES.—F. W. T. Neizert (*Tonind. Ztg.*, 41, 536, 1917). Particular reference is made to electric furnaces for making calcium carbide.

PROPERTIES OF RED EARTH (TERRA ROSSA).—W. Graf (*Tonind. Ztg.*, 41, 603, 610, 1917). The composition of materials from various localities is given, including laterite from the Seychelles, and also mechanical analyses of several. References to other publications are given.

HEAT INSULATION TESTER.—(*Tonind. Ztg.*, 41, 719, 1917). A descriptive account of Gary and Dittmer's apparatus.

HEAT CONDUCTIVITY.—F. Tschaplowitz (*Tonind. Ztg.*, 41, 732, 773, 1917. Also *Ker. Rund.*, 25, 173, 1917). A theoretical discussion.

SHRINKAGE.—R. E. (*Tonind. Ztg.*, 41, 769, 1917). A short theoretical discussion.

TRANSMISSION OF HEAT BY INSULATORS AND BUILDING MATERIALS.—(*Tonind. Ztg.*, 41, 789, 1917). Results obtained with various materials by Gary and Dittmer's heat insulation tester.

INFLUENCE OF GROG ON THE FINE CRACKS IN DUTCH TILES.—G. Heinstein (*Tonind. Ztg.*, 41, 910, 921, 932, 949, 1917). An elaborate investigation. As means for removal of fine cracks by changing the body are mentioned finally (*a*) stronger firing of the tile or the grog, (*b*) finer grinding of the grog and quartz, (*c*) reduction of felspar content at the expense of clay substance, quartz, or chalk (but difference in influence of felspar and kaolin small), (*d*) reduction of raw clay with increase of quartz, (*e*) reduction of quartz with increase of strongly calcined clay, (*f*) reducing raw clay and increasing strongly calcined clay, (*g*) increase of plastic clay at cost of kaolin—both raw and calcined, (*h*) increase of calcium carbonate at cost of felspar, raw and calcined clay or quartz, (*i*) substitution of plastic clay by one which burns hard, or by one which though in other respects the same has less tendency to produce fine cracks.

PLASTICITY.—E. Podszus (*Kolloid-Zeits.*, 20, 65, 1917). A discussion of the factors which determine the plasticity of moist clay, with special reference to application in the ceramic industries.

The author considers that the coagulation of substances in the sol form is an essential feature. He points out that many substances other than clays may be transformed into sols with plastic properties similar to those of clays.

AGREEMENT BETWEEN CERAMIC BODIES AND GLAZES.—F. Singer (*Ker. Rund.*, 25, 211, 217, 223, 235, 1917). A discussion of the subject, based on the results obtained by Seger and later investigators.

IMPORTANCE OF CHEMICAL ANALYSES AND FORMULÆ IN CERAMICS.—R. Rieke (*Ker. Rund.*, 25, 229, 235, 241, 1917). As regards clays, apart from purely scientific investigations, a chemical analysis will only be undertaken when the knowledge of the quantity of the single ingredients is necessary for a certain purpose, thus particularly in the refractories industry, where it is of interest to know the content of the raw material in alumina, and above all in the flux-forming oxides, iron oxide, titanium oxide, lime, magnesia,

and alkalies. In the other branches of ceramics, in which the physical properties of the clay materials come more into the foreground, the question is mainly the determination of individual ingredients harmful or useful, for a particular kind of use. With a brick clay, *e.g.*, the quantity of soluble salts present in other branches of the manufacture must be known, as in the production of Dutch tiles, etc., where the knowledge of the content of calcium carbonate is often sufficient for forming the body mixture. In fine ceramics, the content of kaolin and other raw materials in colouring substances (iron, manganese, and titanium), should be known.

When chemical analysis is necessary, there are no simple and rapid technical methods of sufficient accuracy in the silicate industry, like those in the iron industry, *e.g.*, the attempt to express the composition of kaolins and clays in molecular formulæ leads to very different results according to the completeness and accuracy of the analysis. Thus, two analyses of the same washed Zettlitz kaolin gave 64·45 silica, 38·05 alumina, 0·80 ferric oxide, 0·20 and 0·30 lime, 0·20 and 0·30 magnesia, 0·90 and 1·00 potash, and 13·42 loss on ignition, and these two analyses by the usual method of calculation gave $1RO.20{\cdot}8R_2O_3.42{\cdot}5SiO_2$ and $1\,RO.16{\cdot}1R_2O_3\,33{\cdot}1SiO_2$ respectively (R_2O_3 including $Al_2O_3 + Fe_2O_3$).

Reference is made to researches by the author in 1910 in which he showed that the influence of equi-molecular quantities of fluxing oxides on the melting point of clays is not equal, as is required by Richters's law; this influence largely depends on the state of sub-division and the chemical combination of the individual ingredients. A calculation of the fusibility from the molecular formula with the aid of a law, of a refractory quotient, or of a graphic method can in the most favourable case only provide approximate values, but never substitutes the practical experimental testing.

Of greater importance than ultimate chemical analysis is rational analysis, supposing no more information is demanded from it than it can give. Rational analysis serves for the determination of (1) the quantity of the ingredients decomposable by sulphuric acid, predominantly consisting of kaolinite ("clay substance") in kaolins and numerous clays, which ingredients are to be regarded as carriers of plasticity, and (2) the predominantly non-plastic residue, producing pure quartz. A separation of this residue into "felspar" and quartz is doubtful, as the presence of felspar is only shown frequently under the microscope in the case of incompletely kaolinised rocks containing orthoclase. The assumption that the decomposed portion consists of pure "clay substance," is just as unauthorized as that the residue contains only quartz and felspar. Every kaolin and clay contains subordinate quantities of the most different minerals, which are reckoned either as "clay substance," quartz, or felspar, according to the degree of action of sulphuric acid on them. If considerable quantities of such minerals be present—as mica, calcspar, pyrites, zeolites, etc.—the applicability of the rational analysis experiences an important limitation, and with brick clays, loams, etc., it would be useless. In such cases other methods of separation must be adopted, suited to the substances. Rational analysis is only of practical value for raw materials consisting mainly of kaolinite and quartz, with only very small quantities of felspar. A kaolin containing large kaolinite crystallites is not easily decomposed by sulphuric acid and has sometimes been reported as rich in "felspar."

In quartz and pure quartz sands the content of silica mostly suffices, with also, in the case of material for use in fine ceramics, the iron and titanium contents. With smaller proportions of silica a determination of the other substances is necessary. As to so-called glaze-sands, porcelain sands, felspar sands, the usual rational analysis in addition to determination of colouring oxides suffices. With the less pure sands molecular formulæ facilitate the reckoning in glazes, but the rational composition of the sand generally suffices. Quartz and quartz sand with high percentage silica can without disadvantage be reckoned as pure silica in the production of bodies and glazes. In like manner the generally very pure potash felspar used in fine ceramics can be

reckoned as $K_2O.Al_2O_3.6SiO_2$. But allowance must be made for considerable quantities of soda, lime, and other oxides, or notable excess of quartz.

The marble, calcspar, and magnesite selected for use in fine ceramic work may be taken as pure, but when magnesite is used for refractory purposes it is necessary to know what is associated with it, and this is also the case with bauxites, quartzites, and other refractory materials. If dolomite be used for glazes the proportion of CaO to MgO should be known.

All other ceramic raw materials, as soda, potash, borax, boric acid, red lead, tin oxide, etc., may for practical purposes be regarded as pure, apart from any water present. Kaolins and clays also contain water.

With reference to bodies, the properties depend mostly on their physical condition and the structure, which are determined not only by the chemical composition, but just as much by the physical condition and the degree of division of the individual raw materials, the burning temperature, and the duration of the burning. It is known that at a definite burning temperature the contraction and condensation of a body are greater the finer the grain size of the components and the longer the duration of the burning. The appearance of many oxides and silicates in several physically quite different modifications of the same empirical molecular composition should keep us from regarding chemical analysis alone as a standard for judging the properties of substances.

From numerous trials and practical experiences, glaze schemes have been set up to give a clear picture of the glazes employable for various ceramic products. According to Seger's procedure it has been customary to alter the molecular composition so that the sum of the so-called fluxes, that is, the basic oxides of monovalent and divalent metals, should amount to 1. Many ceramists therefore wrongly designate every molecular formula a "Seger" formula. The fundamental idea at the introduction of these glaze formulæ was that the molecular ratio of the basic oxide to silica and to alumina is decisive for the fusibility and other properties of a glaze. This assumption is, however, only conditionally correct. Glazes of the same type, that is, with the same proportion of $RO : Al_2O_3 : SiO_2$ can show a very different behaviour according to the kind and number of the oxides collected in the RO. Thus, glazes with alkali content predominating show a greater coefficient of expansion, and those with higher zinc content tend towards devitrification and to crystallization. Further, the melting temperatures become lowered by introducing a greater number of oxides into the RO group.

Still greater objections to the suitability of the usual glaze formulæ arise, when substances whose action can be different according to conditions should be provided for. This is especially the case with boric acid, which is mainly put with the silica, but in many cases exercises no opposite influence. To reckon it simply from its formula B_2O_3, corresponding to alumina, as has happened recently in several instances, is still less correct, since in any case it plays quite a different part. Still more difficult is it to provide for Fe_2O_3, TiO_2, SbO_2, ZrO_2 or even F in the glaze formula. Of course iron, if it is obviously present in the glaze as ferrous oxide, can be reckoned as FeO in the RO group. TiO_2, SnO_2, SbO_2, and ZrO_2 dissolve in glazes or enamels only partially, in quantities depending on the composition and the firing temperatures, and these cannot therefore be grouped as acids with the silica, but they must be introduced under a separate heading in the glaze formula as insoluble constituents. The allocation of fluorine in the ordinary glaze formulæ is also inconvenient, because it has been established that fluorine is present in clear glazes.

The conclusion must be drawn that the glaze formulæ of to-day do not give a simple and unequivocal representation of the action of the individual components and of the properties of a glaze.

The practical object of the glaze formulæ is to seek an expression for comparing different glazes more easily, and to give clear formula representations rapidly. These apparent advantages are only partly realised. It is not disputed that in many cases the glaze formulæ are better than percentage compositions, yet that also is partly only a consequence of custom. Glazes whose formula representations are quite similar to one another often show great differences in their chemical composition than might

be supposed from the formulæ at first view. Compare, *e.g.*, the two following glaze formulæ: (1) $0{\cdot}7PbO.0{\cdot}3K_2O.0{\cdot}3Al_2O_3.2{\cdot}5SiO_2$, and (2) $0{\cdot}3K_2O.0{\cdot}3CaO.0{\cdot}3Na_2O.0{\cdot}1MgO.0{\cdot}2Al_2O_3.2{\cdot}5SiO_2$, of which (1) seems to contain more alumina than (2), while the molecular silica is the same (2·5) in both. The percentage of alumina is 8·4 and 8·5 respectively, of silica 41·31 and 63·1. Such a difference in composition is associated with difference in properties.

In the glass industry, in which frequent attempts have been made to investigate a regular connection between chemical composition and properties, percentage composition is always the starting point, not molecular formulæ. The glaze formulæ now adopted in ceramics, which (particularly to students) undoubtedly offer many advantages, should therefore always be completed by also using percentage composition. By this the differences in composition become clearer, and it offers a better opportunity to find out connections with the properties.

A brief reference is also made to the effects of impurities in raw materials, and to losses through volatilization, and also in the case of fritted glazes to material taken up from the vessels. If necessary a chemical analysis of the melted glaze should be made, especially when the mixture contains fluorine compounds and other readily volatile components. In practice such accuracy is generally not necessary for ordinary glazes, and the approximate values calculated from percentage or molecular composition serves. In such cases it is useless to calculate percentage or molecular numbers beyond at most two decimal places

With respect to colours very little is known as to their constitution, and it is well to assume that in most cases no constant molecular proportion must be observed in order to obtain a definite tint. The colours are mostly intimate mechanical mixtures or solid solutions, seldom uniform chemical compounds. Their composition is for the present purely empirical, depending on long practical experience. Often physical considerations, as degree of sub-division, are more important than the chemical composition. But composition is by no means to be disregarded.

SUBSTITUTION OF NORWEGIAN FELSPAR BY PEGMATITE.—H. Fritz (*Ker. Rund.*, 25, 255, 1917). A numerically worked-out example, showing how the substitution is arranged for body and glaze respectively, assuming the chemical composition of the pegmatite to be known, and also the rational composition of the body and the Seger formula of the glaze.

CONTRACTION OF TILE BODIES.—G. Heinstein (*Ker. Rund.*, 25, 287, 1917). See abstract from *Tonind. Ztg.* (41, 353, 1917).

CONTRACTION AND POROSITY DETERMINATIONS.—R. Rieke (*Ker. Rund.*, 25, 259, 263, 267, 1917). Stress is laid on the importance of the firing conditions—temperature and nature of heating (duration of firing, rate of rise of temperature). Linear contraction is commonly determined by measurement of the trials before and after firing by means of a sliding gauge. The total percentage of contraction from the size in moist condition should be determined—not by addition of percentages of drying contraction and firing contraction, which would give too high a value. Generally only the linear contraction is measured and given as a percentage of the original length, the surface contraction and volume contraction being approximately twice and three times as much respectively. A table is given showing the exact values of the two latter for linear contractions of 1 to 20 per cent. For very small contractions the volume is determined before and after firing, the percentage of volume contraction C being then $100(Vu-V)/Vu$, or $100(1-V/Vu)$, where Vu is the volume of the unburned, and V that of the burned trial. In case of an increase on burning the percentage increase of volume is $C_1=100(V/Vu-1)$. To get the percentage volume contraction of trials already fired, it is simply necessary in the above to put the corresponding values after the first and second firing in place of unburned and burned. If necessary, the linear contraction can be

calculated from the volume contraction, for the linear contraction $a = 100 - 10\sqrt[3]{1000 - 10C}$, or from volume before and after firing $a = 100\,(1 - \sqrt[3]{Vu\,/\,V})$. If the volume of the unburned trial is not known, or cannot be accurately determined, it can be calculated from $Vu = 100V/(100 - 3a - 3a^2/_{100} + a^3/_{10000})$.

The volume of quite regularly formed bodies (cube, sphere, etc.) can be ascertained by simple measurement, but these cases are of rare occurrenc. The volume may be ascertained by means of the volumenometer (Seger or Ludwig). Thoroughly compact samples should be saturated with water before measuring, so that water-absorption may be found at the same time. The saturation is effected by boiling the weighed sample with water for a long time, allowing to cool under water, drying superficially with a soft cloth, weighing quickly, and placing in the volumenometer for the determination of total volume. Saturation with water is often not complete, especially with samples having very fine pores. For accurate determinations it is therefore better to lay the sample first in a basin of water with the upper surface of the sample still uncovered, and after 24 hours adding more water, allowing to stand a further 24 hours, then bringing the whole for 15 to 20 minutes under the air-pump, when the last portions of the air escape. With unburned samples toluol may be used instead of water, or for only total volume, the sample may be dipped in melted paraffin.

From the weight of the dry sample (D), the weight of the sample saturated with water (M), and the total volume V, the apparent specific gravity (weight of 1 ccm. inclusive of pore-spaces) $d = D\,/\,V$. The total volume (measured in the volumenometer) consists of the volume of the material and that of the pore-spaces present. In the absence of pores, the apparent density is equal to the specific gravity, but in all other cases it is smaller in value.

The water-absorbing power per cent. of the weight of dried sample (often not quite correctly called porosity in percentage weight) $W = 100\,(M\,/\,D = 1)$, and the apparent porosity (or space occupied by open pores, expressed as a percentage of total volume) $P = 100\,(M - D)\,/\,V$. For true porosity, the total pore space (including pores closed by sintering) has to be taken into account.

If the body saturated with water be weighed while suspended freely in water by a thin wire, and the weight be G, the apparent porosity $P = 100\,(M - D)\,/\,(M - G)$. By using G the apparent specific gravity may be ascertained without measuring the volume, for $d = D/(M - G)$. By coating the sample with melted paraffin, d can also be calculated without determining the volume.

Specific gravity (S) is approximately $D\,/\,[V - (M - D)]$. Similarly, from corresponding values before burning, $S_1 = D_1/\,[V_1 - (M_1 - D_1)]$, and the percentage decrease of the specific gravity, $Fs = 100\,(1 - S\,/\,S_1)$, the increase of specific volume of the material (without the pores), $Rv = 100\,(S_1\,/\,S - 1)$. If the specific gravity increases on burning, and specific volume decreases, the addition is calculated as $Zs = 100\,(S/S_1 - 1)$ and the decrease of specific volume as $Fv = 100\,(1 - S_1/S)$.

Without determination of volume, the specific gravity is $D/(D - G)$.

For more careful measurements it is advisable to determine the specific gravity directly on the previously powdered material with a small pycnometer, thoroughly boiling (with the water at first), and eventually using an air-pump for complete removal of adhering bubbles. From the weight W of the dried powder, with p the weight of the pycnometer filled with water, and p_1 the same including the powder, the value of the specific gravity $S = W/\,[W - (p_1 - p)]$. From this true specific gravity the specific volume (or volume of 1 c.c. of the material) is obtained as the reciprocal $1\,/\,S$.

The true porosity (or total volume of pores) is $P_1 = (V - D\,/\,S)\,/\,V = 100\,(1 - Vm\,/\,V)$, where Vm is the volume of the material, and P_1 is expressed as a percentage of the total volume.

Two ideas less frequently used are degree of density, having a value represented by $d\,/\,S$, and its complement, represented by $1 - d\,/\,S$.

THE RESILIENCE OR IMPACT TEST.—N. M. Howe (*Met. Chem. Eng.*, 17, 298, 1917). The present evidence goes far to prove that the static tensile test

does not and cannot determine the fitness of material for resisting shock when in pieces which are threaded, nicked, or of equivalent abrupt change of section, and hence for such services this test should be supplemented by an impact test.

Resilience is now used as the measure of the work done in breaking the test-piece by a shock test. It is the product of the average resistance to deformation up to rupture into the deformation before rupture, and thus it corresponds in a sense to the product of the tensile strength into the elongation of the static tensile test. It is measured in kilogram-metres (kg-m.). It is perhaps more usefully regarded as the measure of the ability to resist shock or "*shock resistance*." As the static tensile test tells whether a test-piece is statically strong or weak, so the impact test tells whether it is *resilient* or *irresilient*. Impact-resistance is more accurate than resilience. Beyond this, the impact test shows the degree of deformation before rupture under shock. This may be called the "*shock ductility*," corresponding to the elongation and the contraction area of the static test, which are grouped together as "ductility." Thus, both file steel and rivet steel are irresilient, for the file steel offers great resistance to each unit of deformation, breaking before deforming greatly, and though rivet steel deforms greatly, it offers but little resistance to the unit of deformation because of its low elastic limit.

The resilience, or work done in rupture, is determined by subtracting from the total energy of the blow the residual energy left after breaking the test-piece. Two prominent types of testing machine are: 1. Those of the Fremont type with a vertically falling ram (terminating below in a knife-edge), in which the residual energy is measured by a spring against which the ram strikes after breaking the test-piece. 2. Those with a swinging pendulum, the impact of which breaks the test-piece, and the pendulum swinging on past the fragments of the test-piece to reach a height which is the measure of the energy residual after causing rupture.

Instead of being broken by bending, the test-piece may be broken tensilely, by setting its length parallel to the path of the falling ram or tangentially to that of the pendulum. Finally, the test-piece may be either notched or plain, or (as the author suggested lately) threaded throughout its reduced section.

The vertically falling ram type has been objected to on the ground of untrustworthy mechanism for measuring the residual energy, though irregular results have been ascribed to want of homogeneity of the material tested. Blank tests might be made by dropping the ram repeatedly from various heights, and noting whether the energy indicated is constant for the same height. To the bending type of test-piece it is objected that the properties are determined at one spot only, the outer fibre immediately opposite the point of impact, and a like objection is made to nicking. It is the properties of the weakest part which should be ascertained if practicable. The nick is apparently necessary in testing materials for service in which the object itself is nicked (as when there is a screw thread), for it would seem that nicked fragility cannot be inferred from the results of an unnicked test. But there is a special form of nicking which does not localize the application of the test so as to probably escape the weaker parts of heterogeneous material, namely, to thread the whole of the reduced section with a sharp spiral thread, and with such a thread rupture should occur at the weakest section in the reduced part of the test-piece. The merit of such a suggestion can be learned only by thorough trial.

The nicked bending test is said to be much cheaper to make than any other. The objection that the bending test and nicked tests in general are likely to miss flaws, defects, and local weaknesses evidently loses force with material known to be homogeneous. Thus it may prove that the objection should be waived in the case of crucible steel and of electric steel cast in ingots as small as those usual in the crucible process. Again, etching tests might establish the homogeneity of the material so fully as to justify waiving these objections in view of the cheapness and convenience of the nicked bending test. In that case, material which etching shows to be heterogeneous might have to pass a special threaded impact tensile test, while for that shown to be homogeneous the nicked bending test could be used.

Stress is laid on the necessity of numerous tests being made with a view to throwing light on the relative merits and the applicability of the several methods of test. The chief questions to be answered are summed up thus: 1. Can either the nicked or the unnicked test be made to give trustworthy results of fitness for both nicked and unnicked impact service? 2. With materials of such a degree of heterogeneousness as ought reasonably to be provided for, can a single-nicked test-piece give a trustworthy measure of resilience? 3. If not, is it more expedient to substitute a two-inch threaded length of impact tensile test-piece for the single nick, or to test of each material so large a number of test-pieces as to insure detecting approximately the weakest section?

PORCELAIN PYROMETER TUBES.—(*Met. Chem. Eng.*, 17, 93, 1917). The Ceramic Section of the National Bureau of Standards produced from American raw materials a highly refractory product of the Marquardt porcelain type for protecting thermo-couples at furnace temperatures. The manufacture of this porcelain was taken up by the Stupakoff Laboratories of Pittsburgh, Pa. It is claimed that protection tubes of "Usalite" (as it is called) will readily withstand exposure to temperatures above 1,650° C. The surface of the outer pyrometer tube is rendered impervious to combustion gases by a highly refractory glaze, while the inner tubes are unglazed. $^{5}/_{16}$ inch unglazed inner tubes resting on supports 5 inches apart broke under a load of 20 pounds applied centrally. Outer tubes of standard size ($^{11}/_{16}$ inch diameter) when similarly tested broke at 212 pounds. An 18 inch outer tube, freely suspended at its upper end, broke under impact test by applying a 50 pound weight to its lower end when swinging from an angle of 90°. Standard Usalite tubes exposed to 1,370° C. in horizontal position and unsupported for 6 inches did not bend during six weeks' continuous service. Usalite tubes brought white hot into the open air neither broke nor cracked. The smaller unglazed tubes withstood sudden exposure to the highest temperature. A glazed outer tube heated to 1,100° C. readily withstood the introduction of cold steel rod nearly filling the bore of the tube.

Platinum and platinum alloys used for thermo-couples, and resistance thermometers, when heated absorb large quantities of gases and metallic vapours, and when in this state they also readily combine with phosphates and silicates. Hence the insulating tubes are slipped into impermeable protection tubes with closed ends. Pure silica and the silica glazes of porcelain tubes at high temperatures devitrify in a reducing atmosphere and combine with alkaline substances. When possible, therefore, the outer pyrometer tubes should be enclosed in others, known as pyrometer tips, which combine mechanical strength with refractoriness and density of structure.

TESTING REFRACTORY BRICKS.—(*Met. Chem. Eng.*, 17, 184, 1917). Tentative tests recommended by the American Society for Testing Materials. As a *slag test for refractory bricks*, it is recommended to drill a hole ½ inch deep on the sides and 2½ inches in diameter, and after removing all loose material the brick is to be heated to testing temperature (1,350° C.) and a known quantity of slag placed in the drilled cavity. When cold the brick is to be sawn by a carborundum wheel so as to cut through the centre of the original cavity, and the area of slag penetration is measured by means of a planimeter. The degree of fineness of the slag did not affect the penetration, and increasing the amount of slag does not affect the slag penetration when reduced to a unit of area exposed to slag action. Also the amount of penetration is not increased by keeping the brick in contact with the slag for longer than two hours. It is recommended to put 35 grams of powdered slag (through 40-mesh) in the drilled cavity after heating the brick to 1,350° C., to hold at that temperature for two hours, and to cool in the furnace. The drilled-pocket method gives more uniform results than immersing bricks (placed on edge) in 1½ inch depth of slag in a refractory tray.

When clay bricks for blast-furnace or similar uses are to be tested, blast-furnace and heating furnace slags are used. Silica bricks for open-hearth use are tested with open-hearth and heating furnace slags.

The slags used in the development of this test were of the following composition :—

	SiO_2	Fe	Mn	Al_2O_3	CaO	MgO	S
Blast-furnace slag ...	38·0	1·5	1·0	14·5	42·0	2·0	1·0
Heating furnace slag ...	35·0	44·0	0·5	6·0	1·5	0·5	—
Open-hearth slag ...	18·4	14·5	5·1	3·8	44·1	6·3	0·4

Testing refractory materials under load at high temperatures requires a furnace and a loading device. The furnace recommended is 14 inches in internal diameter, and is heated with gas or oil and compressed air, the burners being so constructed and arranged as to give uniform temperature in all parts of the furnace and be under complete control.

The details of the method of loading are shown in a figure.

It is better to have the cross-beams as light as possible, so that most of the load may be concentrated in the weights. The temperature may be measured either with a calibrated platinum-rhodium thermocouple (with junction within 1 inch of side or edge of specimen and opposite the centre, and with cold end kept in melted ice), or with an optical pyrometer which has been calibrated against a thermocouple in the furnace.

The test specimen is a standard 9-inch brick placed vertically on end, or a similar piece cut from blocks or shapes. It occupies the centre of the furnace, and rests on highly refractory material having minimum expansion or contraction ; a silicon carbide brick has been found satisfactory. On the test specimen is placed a block of similar material extending through the furnace top to receive the load.

The rate and time of heating suggested are shown in the table :—

Material	Temperatures (degrees C.) to be maintained at the Time Intervals Specified					
	1 hr.	2 hrs.	3 hrs	4 hrs.	4½ hrs.	6 hrs. (End of Test)
Silica Material	200	500	900	1350	1500	1500
Fire clay (Heavy duty ...	500	900	1150	1300	1350	1350
Fire clay (Moderate duty	500	850	1100	1250	1300	1300
Fire clay (Light duty ...	500	750	950	1050	1100	1100

For general purposes a load of 25 lb. per square inch is recommended. After 6 hours the furnace is left to cool for not less than 5 hours before removing the load and examining test specimen. The test specimen should be measured before testing, and remeasured after cooling to room temperature.

Crushing test may be made with any standard testing machine (Olsen, Riehlé, etc.). The brick, after making the ends parallel, is measured, placed in a cold furnace and heated at a uniform rate up to 1,350° C. in not less than 6 hours, and the final temperature maintained at least 2 hours. The brick is then quickly removed and placed on end on the testing machine, with a thin piece of asbestos board above and below the brick. The machine is started and operated until the brick is crushed, and the crushing strength (pounds per square inch) is recorded.

DISADVANTAGES OF CHROME BRICKS.—F. R. Pyne (*Met. Chem. Eng.*, 18, 20, 1918). Notes from a paper read at the American Institute of Mining Engineers, New York. Several years ago basic refractory material was substituted for silica bricks in the walls of reverberatory furnaces for treatment of very foul blister copper, the latter having exerted rapid corrosive action on

the siliceous linings. Magnesite bricks were tried first, with the result that both corrosion and the amount of slag formed were very much less, but the alternate heating and cooling caused the bricks to crack and spall badly in certain parts of the furnace. Chrome bricks were next substituted for magnesite bricks in the parts of the furnace affected, and so far as the reverberatory furnace was concerned the results were very satisfactory, there being little corrosion, no more slag than with magnesite bricks, and no tendency to crack and spall. Chrome bricks were gradually introduced into all furnaces, those treating blister copper as well as those melting cathodes, and were even extended into the roofs except in certain places where silica bricks were found to be better. Metal absorption was found to be very heavy, both with magnesite and chrome bricks, but it was felt that the long life of the furnace and the decreased cost of slag treatment and metal losses would more than offset the disadvantage. The resulting cobbing is removed when the furnaces are under repair, and its treatment for the recovery of the copper, silver, and gold contents has caused some difficulty. The most satisfactory method yet found for disposing of this material is to grind it to free the larger metallic particles, and to use the fine material for making refractory bricks, the cobbing being thus used repeatedly. There are possibilities of treating the waste material by converting it into ferro-chrome or by making chromate salts.

CLAY FOR GRAPHITE CRUCIBLES.—(*Met. Chem. Eng.*, 18, 265, 1918). The two important ingredients in these crucibles are graphite and plastic clay. Graphite, being a lubricant,, is difficult to bond, and requires a clay of high plasticity and adhesiveness with a high drying and heating strinkage. Before the war all the clay used for crucible purposes in America was imported almost exclusively from Klingenberg in Germany.

One interesting clay which has been produced is the so-called K-10 synthetic clay, developed at the Kraus Research Laboratories in New York and originally marketed by Chevalier & Tully of Baltimore, Md., but now handled by the Johns-Manville Co., who plan to market it on a large scale.

The clay is produced by making extractions from various clays, etc., which are so combined as to produce a fine-grained, highly plastic refractory mass having excellent bonding power. The shape of the grains must be such that the clay when moistened and dried will have high mechanical strength. Modulus of rupture tests on this and other clays gave the following results:—

	Modulus of Rupture lb. per sq. in.	
	Raw	Mixed with 80 per cent. Non-Plastic Material.
K-10	552	518
Klingenberg ...	374	381
Mississippi ...	507	168
H. & W. ...	310	67
Illinois	156	212

The following qualities are considered requisite for a good crucible clay: plasticity, adhesiveness, raw strength, density at low temperature, chemical balance, resistance to metals in fusion, high melting point, high shrinkage on drying, high shrinkage on heating, and low coefficient of expansion.

FURNACE FOR TESTING REFRACTORY MATERIALS UNDER LOAD. —R. J. Montgomery (*Met. Chem. Eng.*, 18, 18, 1918). An illustrated description of a furnace which has been in use for two years with complete satisfaction.

The furnace chamber is circular, 18 inches internal diameter and nearly the same in depth, and may be built of 9 in. wedge bricks, leaving vent holes at various points for inspection purposes. The chamber is heated by two burners using gas and compressed air, the burners being placed tangentially to the chamber. This type of burner gives a whirling action to the flame and a very even heat distribution. The gases escape through a 4-inch circular flue in the centre of the bottom (between the test bricks), which leads to the stack.

To ensure the furnace being full of gas, and to help in regulating the mixture of air and gas, small vent holes are left open near the top, one above each burner.

The test bricks are set on end on a refractory block. On the bricks are placed cups supporting refractory rods which extend through the top of the furnace. This cup and rod arrangement was found necessary for very severe tests, such as 100 lb. per sq. inch at 1,500° C. If built of refractories of the same quality as the material tested the furnace will work satisfactorily. The cup takes the highest temperature of the furnace and will not last through many tests, but protects the rod, which will last very well. To stand the strain of severe conditions the rod's cross-sectional area should be about half as much again as that of the test-piece. The design might be changed somewhat when special refractories are available.

On the refractory rod is placed an iron cap containing a steel knife edge, which engages a grooved plate on a horizontal beam. This beam is pivoted on a support at one side of the furnace, and is balanced by a counterpoise. The beam is kept true by vertical guides, and its height is adjustable. The guides are drilled every inch for a pin support for the beam when the furnace is not in use. The beam acts as a lever of 1 : 4, the load being placed on the hook at the end of the beam. A beam $\frac{3}{4}$ inch $\times 3\frac{1}{2}$ inches will take a load of 25 to 35 lb. per sq. inch on a standard-sized firebrick without undue deflection, and one $\frac{3}{4}$ inch $\times 3\frac{1}{2}$ inches will take a load of 75 to 100 lb. per sq. inch. The beam is levelled at the beginning of the test, and it is not necessary to readjust after starting. The distance between the pivot and the knife edge is great enough not to cause any noticeable eccentric loading. With as high as 15 per cent. shrinkage on the test brick the bar is not very far below the original level. By not adjusting the beam a drum recorder may be used to make a complete record of the test. A pyrometer with a three-foot element is inserted through the central hole in the cover and extends to the centre of the combustion chamber. The cold junction of the couple is protected by an asbestos guard and a correction is made in the readings by adding half the cold junction temperature to the galvanometer reading. The recording device gives a movement three times that of the test brick.

The cover of the furnace is made of two equal parts to allow easy adjustment and placing of the test-pieces and pyrometer.

The refractory ring or block on which the test bricks are set, cracks easily in operation, and could be replaced by two highly refractory bricks or special refractory blocks.

The main points in the design are: 1. Two bricks may be tested at the same time. 2. A down-draught feature which increases the uniformity of the temperature throughout the combustion chamber. 3. The circular combustion chamber and tangential burners give better heat distribution than burners placed at right angles to the furnace. 4. A proper proportioning of the refractory cup and rods allowing maximum temperature and load to be used for the refractory tested. 5. A simple means of applying the load and of obtaining a continuous record of the test.

BAUXITE PRODUCTS.—J. M. Hill (*Mining Press*, 267, Feb. 23rd, 1918). Abstracted from a paper entitled "Bauxite in the South" (*Manufacturers' Record*,, Dec. 27th, 1917). The exploration of bauxite ground and methods of mining are briefly alluded to. The States where it is mined are Arkansas, Alabama, Georgia, and Tennessee. The bauxite is sometimes sent away in the "green" or undried state, but some firms despatch only kiln-dried ore. The drying equipment is simple, mostly consisting of a small wood-fired rotary kiln similar to a cement kiln, but smaller. The loss of the uncombined water reduces the weight of the green ore 10 to 15 per cent.

Bauxite products in order of importance are (1) metallic aluminium, (2) alum, aluminium sulphate, and aluminium chloride, (3) artificial abrasives, and (4) bauxite refractories. The products derived from bauxite have a value which may be 15 to 20 times the value of the bauxite itself.

Brief accounts are given of the modes of preparation of the several products. Bauxite abrasives, under the trade names alundum, aloxite, exolon, and lionite are made by four companies in the United States. They are made by fusing bauxite in a simple electric furnace, the cooled mass being broken, ground and sized, and the products being powder, cloth, stone, and wheels.

Bauxite refractories, or closely analogous products, are made by washing the crude bauxite, and calcining at a high temperature to drive off the combined water. The calcined material is ground, bonded with fireclay, sodium silicate, or lime, and moulded, the shaped articles being dried, and burned in down-draught furnaces. A relatively new development in bauxite refractories is the use of fused bauxite, either in moulded form or as ground or pulverized material for incorporation into refractory cements. Of this class of refractories, which are made in electric furnaces, some are pure fused alumina, and are extremely refractory, melting at temperatures of 2,050 and 2,100° C.

REFRACTORY FURNACE LINING.—J. B. A. Steurs, Fr. Pat. 481,230, Nov. 14th, 1916. The furnace lining is composed of carborundum, aloxite, pure clay (kaolin), and chrome ore; as binder is used potassium and sodium sulphites, and resin dissolved in alcohol. The proportions may be 35 carborundum, 25 aloxite, 20 clay or kaolin, 20 chrome ore, and the binder may consist of 54 potassium sulphite, 24 sodium sulphite, with 22 resin dissolved in alcohol.

BASIC REFRACTORY FURNACE LININGS.—H. A. Kennedy, U.S. Pat. 1,238,020, Aug. 21st, 1917. The material is produced by clinkering in a rotary kiln a mixture of lime and magnesia (together 78 to 92 parts), silica (2 to 13 parts, and an oxide fluxing agent (6 to 14 parts) such as aluminium and iron oxides.

REFRACTORY MATERIAL FOR FURNACE LININGS.—P. R. Hershman, U.S. Pat. 1,240,569, Sept. 18th, 1917. A moulded mixture of 100 parts Al_2O_3, 15 to 30 coke, 2 to 5 hard pitch, and 25 to 30 parts concentrated slaughter-house "tank water," is sintered or fritted together. The product is moulded under high pressure and gradually heated to 1,850°.

REFRACTORY SILICEOUS MATERIAL FOR BRICKS.—J. Bied and P. Offant, Fr. Pat. 482,177, Feb. 27th, 1917. A siliceous earth ground and mixed with a small proportion of flux is charged into refractory earthen moulds, and subjected to prolonged heating at a suitable temperature. The slabs thus produced are cut into bricks.

REFRACTORY SUBSTANCES.—C. B. Stowe (*Pat. J.*, No. 1,506, 1917). Pat. No. 110,147, Oct. 6th, 1916. Magnesite is mixed with iron oxide (as rolling-mill scale), ground and brought to the consistency of mud with water. The mixture is moulded with bricks, etc., dried, and burnt at a temperature of cone 11 to cone 19 to expel CO_2 and cause combination between the magnesium and iron oxides. The material when crushed may be used for furnace linings, or it may be mixed with new magnesite, magnesia, or iron oxide, and the process repeated. Bricks, crucibles, etc., may be made from the crushed product of the first burning by grinding with water, spreading on a floor to allow any unslaked lime to slake, again grinding and moulding. The bricks, etc., are then dried and burnt to the point of vitrification. The grinding and burning operations may be repeated several times.

REFRACTORY SUBSTANCES.—H. A. Kennedy (*Pat. J.*, No. 1,516, 1918). Pat. No. 111,853, Nov. 26th, 1917. A refractory material for furnace linings, etc., is made by clinkering, at a higher temperature than that for making Portland cement a finely divided intimate mixture of about 78—92 parts of lime and magnesia (preferably from dolomite) 2—13 parts of silica and alumina or iron oxide or both. To a certain extent alumina and iron oxide may be replaced by silica, or in their place basic slag, blast furnace slag, bauxite, chrome iron ore, etc., may be employed.

BARIUM HYDRATE AND SILICATE.—C. Degnide (*Pat. J.*, N. 1,509, 1917). Pat. No. 110,537, Sept. 29th, 1916. Barium carbonate is calcined with silica at 1,400—1,500° C. in the proportions to produce Ba_2SiO_4. The product, which is not fused, is treated with hot or cold water, when half of the barium becomes hydrate, which dissolves, leaving $BaSiO_3$, which is separated, washed, mixed with barium carbonate, and heated to 1,400—1,500° C. to obtain Ba_2SiO_4 again. The barium hydrate may be used in an industrial process in which it is recovered in the form of carbonate, which may then be used in the main process.

TESTING HARDNESS OF METALS.—D. Chattaway (*Pat. J.*, No. 1,529, 1918). Pat. No. 114,126, Dec. 8th, 1917. Relates to apparatus of the kind wherein a ball of superior hardness is forced against the metal to be tested.

TESTING HARDNESS OF METALS.—Reid Bros. and G. Brown (*Pat. J.*, No. 1,533, 1918). Pat. No. 114,593, May 22nd, 1917. The metal is subjected to a blow imparted to a freely movable head having a hard point, the hardness being measured by the depth of the indentation. The blow may be given by a falling weight, and the measurement may be made by optical means.

TESTING HOLLOWWARE.—Everton & Wilson, Ltd., and A. T. Padmore (*Pat. J.*, No. 1,536, 1918). Pat. No. 115,121, May 22nd, 1917. A machine for testing hollowware, comprises a tank, a holder above the tank for the article to be tested, a pressure gauge in communication with the holder and the article under test, means for supplying air under pressure to the article, and means for immersing it gradually in the tank.

TESTING HOLLOWWARE.—W. E. Morum (*Pat. J.*, No. 1,536, 1918). Pat. No. 115,133, June 20th, 1917. Hollow bodies such as hand grenades are tested for air-tightness by submitting them to the action of air above or below atmospheric pressure, and observing the steadiness of a column of liquid in the connecting pipe between the source of the air supply and the article under test.

HIGHLY REFRACTORY VESSELS FROM NON-ARGILLACEOUS MATERIALS, PARTICULARLY ZIRCONIA.—H. Arnold (*Chem. Ztg.*, 42, 413, 426, 439, 1918). Carbon, though capable of withstanding the high temperatures now reached in many heating operations, has disadvantages from its combustibility and reducing action. Hence efforts have been made to produce vessels of silica, alumina, magnesia, zirconia, thoria, rare earths, etc. Some of the materials, as the very refractory thoria, are too expensive, others, like magnesia, have at high temperatures (say 2,000° C.) so high a vapour pressure that the strength and density of the vessels suffer.

Zirconia when pure melts at about 2,600° C., and was obtainable before the war at relatively low price. Without suitable treatment, zirconia is thoroughly non-plastic and difficult to work. Hence special attention was first given to the pressing process, for which in ceramics the smallest degree of plasticity is necessary. By the use of binding materials, which are less refractory and volatilise in the burning, less dense and very porous vessels are obtained; such vessels also show a tendency to become blistered, distorted, and cracked. This suggests the use of pure zirconia for the best results. While almost all substances lower the melting point and the refractoriness of zirconia utensils, in the production of such ceramic objects as are burned in the electric furnace or are employed later, the electrical conductivity of the oxide used also plays an important part. Zirconia even proved to be specially suitable as a solvent for other oxides. Pure zirconia has a specific conductivity at 1,200° C. of 0·0008, at 1,400° C. of 0·0034 reciprocal ohms. The addition of one molecule alumina to 9 molecules zirconia increases the conductivity at 1,200° C. to 0·00255 reciprocal ohms. With cerium dioxide substituted for the alumina the conductivity at 1,000° C. is 0·0075, and a like substitution of ferric oxide gives a conductivity at 1,287° C. of 0·0358. Titanium dioxide and other substances have only an insignificant effect on the conductivity, and in practice it may often be of great advantage to keep the conductivity as small as possible—

always (for example) when melting metal in a transformer crucible furnace, as vessels made of unsuitable mixtures might here prove unemployable although their refractoriness is sufficient Native zirconia, like that from Brazil, conducts the electric current very well.

Reference is made to pioneer work of Weiss, who obtained his best results from a mixture of 9 parts zirconia and 10 parts magnesia, with phosphoric acid to form a stiff paste.

Zirconia has a remarkably low thermal coefficient of expansion—amounting to $8{\cdot}4\times10^{-7}$ as compared with 7×10^{-7} for quartz—which enables it to resist strongly sudden changes of temperature.

The investigations of Ruff and Lauschke are briefly alluded to (see TRANS., 16, 126, 1917).

According to the author's experiments, the use of water is important because the enclosed air bubbles, which give rise to the formation of cracks, are driven out by pressure. Hence the quantity of water to be used varies with the pressure (see German patent 285,934, and U.S. patent 1,121,889), and crucibles 70 mm. high and 70 mm. diameter can even be pressed completely dry at a pressure of 300 atmospheres. If the zirconia be hot in the mould, or if a heated mould be employed, the same result can be obtained with 50 atmospheres pressure. The expulsion of air bubbles is in this way favoured and later cracking obviated. For the burning a small addition of other oxides, like alumina, is advantageous, on account of the contraction setting in earlier, perhaps owing to a kind of spinel formation.

Mixtures of raw and strongly calcined zirconia can be burned much more quickly and with considerably less waste. The preheating in the gas kiln is saved altogether, and the heating in the electric furnace at 2,000° to 2,300° takes only about an hour for crucibles 45 mm. high and 28 mm. diameter.

The theoretical and practical investigations of Rohland, Förster, Weber, Schwerin, and others have finally led to the result that zirconia can now be treated ceramically like clay, and accordingly the usual processes of moulding and casting are technically far superior to the pressure process, not only by a great saving of time but also by omission of the expensive steel matrix-die, which wears out rather rapidly. Instead of these can be used cheap, quickly produced, and easily replaceable plaster moulds. Further, moulded and cast vessels have a considerably smaller weight than pressed, and can be produced with any desired thickness of wall, especially with quite thin walls. A further advantage is the possibility of preparing even quite complex objects of highly refractory materials.

Podszus employed for the zirconia binding and sintering substances like phosphoric acid, borax, and potash, which volatilise on burning, and moulded the ground material with the aid of glycerine. Since the bodies so obtained are still very porous after the preliminary burning, they are subsequently covered with one of the easily evaporating substances mentioned, and then burned dense in consequence of the sintering arising from the addition. This process is an attempt to avoid using extremely high temperatures.

Rieke cast crucibles of various sizes of purified Brazilian zirconia, simply applying the methods of Keppeler and Spangenberg (German patents 201,404, and 201,987, 1908), in order to make capable of casting or binding, clays or kaolins which are incapable of casting. He incorporated with the non-plastic 96 per cent. zirconia the colloid substances needed to make it plastic, using the humous substances mentioned in the patent specification. Such crucibles, evidently cast from zirconia or zircon sand, were supplied commercially by a German firm. Bayer used an inorganic colloid along with an organic one, namely, a jelly of an intimate mixture of hydrated zirconia with starch-paste solution. In such mixtures the precipitated and well-washed hydrated zirconia partly changes into the sol condition. The jelly was mixed with calcined zirconia or with Brazilian zirconia to a good kneadable mass and pressed by means of a wooden die in a plaster mould rubbed out with graphite powder.

With reference to casting, the fact that many clays by addition of alkali become more fluid and better for pouring was mentioned by Brongniart as far

back as 1844: Weber greatly extended the application of this (German patents 158,496 and 159,193, 1905; also No. 224,098, 1910, and English patent 12,535, 1910). He found that not only clays were thus improved, but also with suitably fine grinding other substances such as quartz, corundum, magnesite, zinc oxide, and that by use of acids and salts the slip became thickened again. This question is discussed at some length, reference being made to investigations by Förster, Böttcher, and Neubert, and with special reference to hydrated zirconia by Herzfeld. For the preparation of such colloidal solutions of zirconia, reference is made to Svedberg's "Methods for the Production of Colloid Solutions" (in German), and to the special compilation in Abegg's Handbook. The author measured the speed of migration of a sol. which was acquired by the hydrolysing evaporation of a solution of hydrated zirconia.

The sol was obtained by Cleve's method of evaporating 50 grms. of zirconium nitrate with a litre of water four times, and the content in colloidal zirconia was determined to be 17·96 g. to the litre by flaking it out by means of concentrated potassium sulphate solution. It is absolutely necessary to carefully wash free from electrolytes zirconia used for ceramic purposes.

Reference is also made to Freundlich's numerical values, and to Graf Schwerin's German patent 274,039 (1914), and that of Podszus (No. 274,847, also French patent 443,956, and English patent 11,771/1912). By very fine grinding and suspension the material assumes a colloidal character, and can then be shaped and cast without binding material, the sol condition being produced; to suspensions of electronegative substances are added bases, and to suspensions of electropositive substances acids. It is perhaps not necessary that the whole material should change into the colloidal condition, but it suffices if that is the case with a part. An example of an electronegative, naturally non-plastic substance is carborundum, and corundum is an example of an electropositive substance.

In his French patent Podszus uses for a non-porous mould a body mixture (for moulding or casting) with additions of binding substances, like gelatine, tragacanth, collodion, etc., but also slowly decomposable salts of the elements concerned, as for example zirconium nitrate. The whole body material is very finely ground (0·005 mm. and less). The mould is produced either from combustible or easily fusible or chemically easily soluble material. The body is then laid on in several layers, which afterwards in the kiln burn to a single layer. The body can be produced with the aid of a mould according to well known ceramic processes by dipping, coating, pouring, or spraying, and Podszus quotes as a special advantage of his process that objects can be produced with greater accuracy, and even hollow bodies with walls only $^1/_{10}$ mm. thick. For use with a porous mould, as a plaster mould, from which after some time the object moulded shall detach itself, Podszus chooses another kind of preliminary treatment of the material.

He proceeds also from the most finely powdered starting material, but produces in it a number of particles of colloidal fineness. Grinding gives particles of 1—5 μ, and colloidal particles vary between 0·1 μ and 1 $\mu\mu$. Podszus regards it as expedient to get the colloidal particles in the midst of the powder itself, and for that makes use of one of the known methods, such as continued hydrolysing evaporation or dialysis. Apart from the colloidal particles, which are only produced in a limited proportion, some ordinary organic binding substance is added.

The action of colloidal particles is discussed at some length.

For the casting process the colloid process must be in the sol and not in the gel state, as Podszus proved. By separation into flakes the gel brings plasticity *in statu nascendi* as it were into the material.

According to German patents 274,847 and 294,796 Podszus brings a fluid body mass produced from very finely divided powder ($\leq \mu$) into a permanent mould of small coefficient of expansion, by dipping, painting over, pouring over, etc., in one or several layers, whereby besides there is inserted between the mould and the cast piece an easily removable non-absorbent intermediate layer. This latter can be made by coating the mould with paraffin, wax, etc.,

whereby through scratching, covering with graphite or application of a protecting layer of gelatine or collodium, it is made suitable for adherence of the body mass. The zirconia should before grinding be heated at a high temperature or melted. The process is particularly suited for very thin-walled bodies. With complicated shape or for hollow bodies a wax mould cannot be used, because wax has too great a coefficient of expension. A permanent mould with the smallest possible coefficient of expansion is then made, as, for example, of nickel steel, and the mould is coated with a thin layer of wax or the like. When the ceramic bodies in the mould are dried, the intermediate layer is melted out, which should be possible with the use of very thin intermediate layers.

The linear contraction of crucibles 10 cms. high and 5 cms. upper diameter with 1 mm. thickness of wall and burned at 2,000° C. amounted to (in percentage):

	Cast	Pressed
Uncalcined ZrO_2	30	25
Addition 30 per cent. previously calcined ...	26·4	21
Addition 50 per cent. previously calcined ...	20	—

Previously calcined zirconia can easily be used as an addition to other ceramic masses. Other vessels can also be provided with coatings of zirconia (German patents 156,756 of Pufahl, and 289,992 of Hedwig Herzfeld). Owing to the anomalous contraction the prospects for production of good coatings of zirconia on other ceramic substances are small.

The furnace gases and air act in different manner at different temperature on zirconia, as is manifested by different colorations. Ruff distinguishes the following substances:

At 2,000° C. blue grey coloration through formation of lower oxide.
At 2,200° C. red brown coloration through formation of lower oxide.
At 2,400° C. blue black coloration through taking up carbon and formation of carbide.

The red brown coloration depends on the simultaneous presence of gold-coloured zirconium nitro-carbide. The author remarks that the coloration, and especially its intensity, is greatly affected by quite small quantities of titanium dioxide, which forms at about 1,500° C. a blue oxide with bronze lustre, corresponding perhaps to the composition Ti_7O_{12}. This very intensely coloured compound chiefly causes the coloration, whereas zirconia quite free from titanium oxide appears at 2,000° C. almost throughout whitish grey.

Pieces of zirconia ware burned in a reducing atmosphere, which have a splendid purple brown colour with bronze lustre, are very strong and hard and difficult to break, and when polished have an appearance recalling black marble. If reduced or coloured objects are heated in a muffle to about 1,000° C., pieces of white to yellow colour are obtained, and the oxidation accompanied by expansion causes cracking and splitting off from the surface. The burned goods also become much more porous and often plain. Addition of small quantities of foreign oxides to the casting slip is helpful, 3 to 5 per cent. of alumina being particularly suitable. An equal percentage of clay or yttria also does good service, the burned vessels in the latter case being coloured a light ochre-yellow. Addition of magnesia furnishes pure white but very porous vessels. Also an addition of silica did not prove good, the burned objects being still porous and having a bad "ring."

When additions are made, part of the added substances volatilises, causing increased porosity. It is necessary, in order to obtain compact objects of zirconia, that in every case the temperature must exceed 1,700° C., for the main contraction sets in spontaneously between 1,600° and 1,700°. This evidently corresponds with a change of the zirconia, which proceeds in like manner with that of chromic oxide at 500° C., and of alumina at 750° C.

Zirconia ware is best supported on zirconia, either plates or rammed powder. Carbon can be used in some cases as special support. Loss can be largely avoided by care in removing the objects from the moulds.

The question of a good glaze for zirconia vessels has not been solved hitherto. This is owing to differences in expansion coefficients and shrinkages, the necessarily high melting points of the glazes and the possibility of the deposition of carbon and reducing gases between the particles or reacting with the glazes, thus hindering the smooth melting. Useful glazes have been employed for certain temperatures. Easily fusible glazes, melting between 1,000° and 1,200° C., must be laid on somewhat thicker, so as not to be absorbed, and for same reason temperature should not afterwards be raised too much. On the contrary by taking up zirconia from the body it becomes more difficultly fusible, and could be used at a higher temperature. A glaze which melts on the ware at 1,900°—2,000° C. has the composition $13SiO_2.0{\cdot}8Al_2O_3.1{\cdot}2ZrO_2.0{\cdot}4K_2O.0{\cdot}6MgO$, and is made up of 222·4 parts felspar, 40·8 alumina, 147·6 zirconia, 50·4 magnesite, and 696·0 quartz; it does not craze, but is rather matt and covered with numerous blisters. With a high content of zirconia the glaze does not craze, but it is matt, rough and unsightly. [We are indebted to the courtesy of the Secretary of the Society of Chemical Industry for the loan of the original.]

ELECTRIC INSULATING MATERIALS.—A. R. Muller (*Pat. J.*, No. 1,542, 1918). Pat. No. 116,532, June 11th, 1917. Electric insulating materials are made from hard pitch, which has been submitted to a temperature of at least 400° C., and asbestos, with or without fillers or colours. A suitable proportion is 25 per cent. pitch and 75 per cent. asbestos. Specifications 18,989/04 and 11,908/10 are referred to.

ELECTRIC INSULATING COMPOSITIONS (PLASTIC).—T. S. Chivers and C. Marter (*Pat. J.*, No. 1,548, 1918). Pat. No. 117,676, July 27th, 1917. They consist of asbestos (50 per cent.), sulphur (25 per cent.), and golden or crimson sulphide of antimony or black antimony (25 per cent.). The ingredients are incorporated by heating and are afterwards ground up and moulded under heat and pressure.

TESTING HARDNESS OF MATERIALS.—W. and T. Avery, and J. Dobson (*Pat. J.*, No. 1,547, 1918). Pat. No. 117,526, Aug. 30th, 1917. In apparatus of the kind wherein a hardened steel ball is forced into the surface of the material so as to cause an indentation, the applied load is transmitted through multiplying levers to a test weight and to an automatic indicating mechanism.

TESTING STRENGTH OF MATERIALS.—W. and T. Avery and E. A. Allcut (*Pat. J.*, No. 1,551, 1918). Pat. No. 118,175, Sept. 22nd, 1917. Relates to apparatus of the kind in which a tensile test is made by the impact of a pendulum or a falling weight. The apparatus is illustrated.

FORMATION OF LAYERS IN SUSPENSIONS OF SOILS AND CLAYS.—P. Ehrenberg, E. Hahn, and O. Nolte (*Kolloid Zeits.*, 21, 1, 1917). From measurements of the concentration and of the number of particles in different layers it is concluded that the stratification arises from the particles so varying in size that they fall into discontinuous groups. In each group the particles approximate in size to the mean size for the particular group, this being appreciably different from the mean size of the particles for the neighbouring groups.

EQUILIBRIUM IN SILICATE FUSIONS.—C. Doelter (*Zeits. Kryst. Min.*, 54, 398, 1914; from *Sitzungsber. k. Akad. Wiss. Wien, Math-nat. Klasse*, 110, 839, 1911). Melting points of many silicates as determined by the thermal method are too high because of under-cooling or over-heating. Except in the case of sodium, lithium, and lead silicates, there is no definite melting point, but rather a range of temperature in the course of which the substance gradually passes from the crystalline, through a glassy amorphous stage, to the liquid condition. As the thermal method is applicable only to substances which melt quickly, the author uses (1) an optical method, in which the melting process is observed directly with a heating microscope, or (2) an approximate

method in which the finely powdered silicate is kept at the sintering temperature until the mass melts completely. The influence of the size of particles may cause a difference of 100° or more. The velocity of melting or crystallizing depends on rate of heating and on viscosity. The laws deduced from the phase rule and from thermodynamic principles are therefore applicable to silicate fusions only in a modified form.

Non-observance of these principles may give rise to large errors. Thus Day and his associates found for wollastonite a melting point of 1,260°, and for calcium α-metasilicate 1,512°, whereas the author found 1,240°—1,320° and 1,310°—1,380° respectively. No molecular change of wollastonite into the α-form was observed, but it was noticed that only the α-silicate separated above 1,260°.

CHEMICAL CONSTITUTION OF BAUXITE FROM BIHAR, HUNGARY.—B. von Horváth (*Zeits. Kryst. Min.*, 54, 182, 1914; from *Földtani Közlöny*, 41, 254, 1911). The Bihar Mountains bauxite deposits are situated on a plateau of Upper Jurassic limestone. The following analyses are given:—

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	H_2O	Total
I.	1·52	3·10	53·20	27·66	0·20	trace	14·39	100·07
II.	1·52	1·95	58·26	30·22	—	0·09	8·09	100·13
III.	12·38	3·95	58·74	7·84	0·32	0·11	16·31	99·65

I and II are analyses of a reddish-brown material from near Vaskoh, and III is that of greyish-white material from Mt. Kuku, near Tizfalu. Twelve other partial analyses of the reddish-brown bauxite gave: SiO_2, 0·92—2·23; Al_2O_3, 39·32—58·60; and another partial analysis of the greyish-white gave: SiO_2, 5·55; Al_2O_3, 52·11.

MICROCHEMICAL REACTIONS OF DOLOMITE FROM KIELCE, POLAND.—St. J. Thugutt (*Zeits. Kryst. Min.*, 54, 198, 1914; from *Kosmos, Lemberg*, p. 409, 1911). The following analyses are given:—

	CO_2	Al_2O_3	FeO	MnO	CaO	MgO	Insol.	Total
I	42·11—47·42	0·04—0·49	0·54—1·35	0·17—0·36	26·55—31·52	18 33—20·59	0·38—10·69	—
II	40·32	1·26	2·17	1·04	26·88	15·68	13·13	100·48
III	49 72	—	8·16	—	0·18	40·99	1·56	100·61
IV	49·63	—	12·42	—	—	38·15	0 27	100·47
V	40·82	—	43·29	—	—	12·89	3 00	100·00
VI	44·47	—	11·41	—	27·55	13·09	2·73	100·15
VII	47·07	—	2·57	—	29·89	20·38	—	99·91
VIII	46·84	—	3·86	—	30·53	18 45	0·31	99·99
IX	46·76	—	1·97	—	29·69	20·94	1·13	100·94
X	47·49	—	1·79	0·25	30·03	20·84	0·05	100·45

I gives the extreme figures resulting from eight analyses, by W. Koziorowski, of Upper Devonian dolomites from various localities in Kielce. The ratio of $CaCO_3 : MgCO_3$ is 1 : 1, some of them containing excess of calcium in the form of calcite as proved by Lemberg's colour reactions with silver nitrate and potassium chromate or iron-alum; II is analysis, by W. Koziorowski, of Triassic dolomite of Suchedniow, containing some aragonite; III represents magnesite from Ekaterinburg, Urals; IV represents breunnerite from Pfitsch, Tyrol; V represents sideroplesite from Heizenberg, Zell, Salzburg; VI represents brown spar from Traversella, Piedmont; VII represents colourless dolomite crystals from Szabra, Ekaterinburg; VIII represents dolomite crystals from Snarum, Norway; IX represents dolomite crystals from Greiner, Tyrol; X represents dolomite crystals from Zabkowite, Moravia.

Dolomite and magnesite, when well crystallized and containing iron, do not react with silver nitrate or iron-ammonium sulphate solution, but the Polish dolomites poor in iron give a distinct reaction at 100° C. The Kielce dolomites show a strong thermo-luminescence at 153° with a fine red colour. Dolomite from Fassa, Tyrol, shows a red luminescence, and calcite from Seiseralpe emits a white light at 118—132° C.

MOLECULAR DESTRUCTION OF KAOLINITE BY HEAT.—A. M. Sokolov (*Zeits. Kryst. Min.*, 55, 195, 1915; from *Ber. Tech. Inst. K. Nikolaus I*, 22, 1, 1913). Gluchov kaolinite was heated at 200—1,000° C. for one to five hours, and the loss of water was determined. The residue was digested with 16 per cent. hydrochloric acid, and the alumina in the solution determined. The alumina was ignited for one hour, and the following results were obtained:

Temp.	Loss of H_2O%	Soluble Al_2O_3%	Molecular ratio $Al_2O_3 : H_2O$
300° ...	0·72 ...	2·12 ...	1 : 1·91
400° ...	0·67 ...	2·08 ...	1 : 2·03
600° ...	10·49 ...	28·46 ...	1 : 2·14
700° ...	11·92 ...	32·30 ...	1 : 2·06
800° ...	12·99 ...	34·66 ...	1· 2·12

With more prolonged heating, slightly higher results were obtained. A weak solution of alkali takes up soluble silica from the residue. At 800° C. the kaolin molecule is completely broken down into its component oxides, and on this Zemiatchensky's method for the analysis of clays is based.

[See also Mellor and Holdcroft on the Chemical Constitution of the Kaolinite Molecule, TRANS., 10, 94, 1911; 11, 169, 1912; 13, 83, 1914.]

SILICATE FUSION SOLUTIONS.—K. Neubauer (*Zeits. Kryst. Min.*, 54, 184, 1914; from *Földtani Közlöny*, 41, 72, 197, 1911). Experiments with mixtures of leucite, orthoclase, and diopside, in various proportions, were conducted under the microscope. Fusion commenced at 1,190°—1,205° (orthoclase melts at 1,190° and became completed near the arithmetical mean of the melting points of the three components. Crystallization began at 1,090°—1,170°, below the melting point of any component. Leucite crystals separated first, then good crystals of diopside which grew very rapidly. Orthoclase separated only in the form of a glass.

CONSTITUTION OF SOME MINERALS OF THE MICA GROUP.—W. Asch and D. Asch (*Zeits. Kryst. Min.*, 54, 584, 1915). In accordance with his theory that orthosilicates can form isomorphous mixtures with trisilicates (and other polysilicates), F. W. Clarke has ascribed very complex formulæ to the alumino-silicates "zinnwaldite" and cryophyllite. The authors contend that the same analyses lead to much simpler formulæ according to the hexite-pentite theory. "Zinnwaldite" thus seems to be a derivative from the alumino-silicic acid $n\,H_2O.2(5Al_2O_3.18SiO_2)$, by substitution of basic atoms for part of the hydrogen and of fluorine for part of the oxygen, the composition of this mineral being expressed by the formula $K_{10}Li_{10}H_4Mn''Fe''_7Al_{20}Si_{36}F_{20}O_{112}$.

The composition of cryophyllite is found to be $H_3K_4Li_5Fe''_{1·5}Al_{55}Fe'''_{0·5}F_6Si15O_{48·5}$, and it can be considered a derivative of the alumino-silicic acid, $7·5H_2O,3Al_2O_3,15SiO_2$

DIFFERENTIATION OF THE INTERNAL STRUCTURE OF DIFFERENT SPECIES OF SILICA.—S. Kyropoulos (*Zeits. anorg. Chem.*, 99, 197, 1917). The Röntgen ray interference pattern method of Debye and Scherrer (*Nachr. k. Ges. Wiss. Gottingen Math. phys. Klasse*, 1916) has been applied to powdered silica. A powdered amorphous substance behaves as a grating of low dispersive power, and a powdered crystalline substance behaves as a grating of high dispersive power. The particles used range from 0·5 to 1 μ in diameter, and are pressed lightly into paper tubes and exposed to platinum radiation. Quartz and cristobalite give similar but readily distinguishable systems of rings, but interference rings are absent from the patterns of quartz glass and precipitated silica, though a silica gel gives a single broad ring. When precipitated silica is heated at 1,300° for two hours, interference rings appear, indicating partial conversion into cristobalite.

FERRIC OXIDE AND ALUMINA.—F. H. Scheetz (*J. Physical Chem.*, 21, 570, 1917). The yellow colour in bricks has been shown previously to be due to a yellow modification of anhydrous ferric oxide, which is rendered stable by alumina. By precipitating solutions containing ferric and aluminium sulphates, with sodium carbonate, sodium hydroxide, and lime, drying the washed precipitates, and gradually heating them to 1,000° C., the precipitates obtained with lime water gave a buff-coloured substance provided the ferric oxide did not form more than 8 per cent. of the mixed oxides. When sodium carbonate or hydroxide was used for precipitation, the buff colour was not obtained.

THE REFRACTORY BRICKS INDUSTRY.—F. J. (*Deut. Töpf.-Zieg.-Ztg.*, 48, 177, 193, 209, 225, 249, 1917). Refractory bricks in Germany fall into four classes:—Class 1. The most highly refractory, melting betwen cones 34 and 36. Class 2. Highly refractory, melting between cones 32 and 34. Class 3. Refractory, melting betwen cones 29 and 32. Class 4. Semi-refractory, melting between cones 26 and 29. For both producer and consumer it should serve as a standard of refractoriness that the melting point of a brick must be at least 300° C. higher than the highest temperature to which it is exposed in the industrial furnace plant. The producer must meet other influences acting injuriously on the durability of refractory bricks by suitable combination of the raw materials employed by their preparation, as well as the shaping and burning. The following table is given as advantageous for confirming the temperatures in the various furnaces and heating plants, for which refractory bricks are needed:—

Appearance of fire	Degrees C.	Seger Cone	Melting Point of Metal
Red hot in the dark ...	400—500	022	Tin, zinc, bismuth, lead
Dark red	650—700	020—018	Aluminium
Cherry red	800—850	015—013a	Bronze
Bright red	950	07a	Silver, brass, enamel colours
Dark orange ...	1,100	1a	Gold, copper, cast-iron (white)
Bright orange ...	1,200	6a	Cast-iron (grey)
White heat	1,300	10	Steel, easily fusible
Bright white heat ...	1,450	15—16	Steel (difficultly fusible), nickel
Welding heat, bluish-white glistening	1,500	18	Weld iron
Platinum-melting heat, white glistening	1,800	34—36	Platinum

It is to be understood in the foregoing that by the melting point of a refractory substance is meant the temperature at which a small trial piece melts completely to a drop.

A general account is given of the refractory clays of Germany, with special mention of certain clays largely used for firebricks in the iron and steel industry, for gas retorts, glass pots, bricks for cupolas; the shales of Neurode and Rackowitz are included. Reference is also made to the chief siliceous refractories (quartzites, quartz sands, sandstones, etc.), and to other raw materials like magnesite, dolomite, graphite, and bauxite. Next grog (schamotte) is considered, and its burning (at cone 10 to 12); if the grog be not strongly burned and the furnace lining sufficiently refractory earlier renewal is necessary. Here is also a brief review of the types of kiln available. The production of grog bricks is described, and then of silica bricks, and also of magnesite, dolomite, and bauxite bricks.

THE PLASTICITY AND STRENGTH OF CLAY.—O. Nolte (*Zentralblatt f. Agrikulturchemie*, 47, 108, 1918; abstracted from *Internationale Mitteilungen für Bodenkunde*, 1916, VI., p. 351). Böttcher (*Über die Verflüssigung des Tones durch Alkali*, Dissertation, Dresden, 1908) sought to prove that to the content of clay in organic substance must be attributed a preponderating influence on the plasticity. He reached this conclusion because a clay treated several times with ether and water lost in plasticity. But by the treatment with water not

inconsiderable quantities of colloid clay could have been removed also, so that the diminution of plasticity can also be attributed to this circumstance.

In order to clear up this question, heavy clay from Silesia was treated exhaustively with ether and acetone, without being able to determine that a decrease of the greasy feel and plasticity took place. The author therefore believes Böttcher's conception cannot be maintained. Against it he was able to make some determinations worthy of notice. Thus after the evaporation of the extracting agents a yellow mass was left, which gave from itself in increased measure the odour perceptible in breathing on clays. However, this substance is not the cause of the clayey odour, for this disappears gradually, especially when it is sought to further purify the wax-like mass. On further re-dissolving with ether and acetone it showed itself as consisting of at least two different substances, of which one was more difficultly soluble in ether and was deposited from this solution in small orange-coloured rhombic crystals. Melting point of 113°, combustibility with blue flame and formation of a gas of pungent odour, pointed to elementary sulphur. The second body was easily soluble in acetone and of organic nature, but was not a paraffin, for it did not burn without leaving a residue and without formation of a characteristic odour. Identification was unfortunately not possible, the quantity present being too small.

In conclusion the author points out that the presence or occurrence of sulphur in clays must be taken into consideration in the determination of organic substance by combustion of the clay in a tube, in order to avert sources of error; the resulting SO_2 must be fixed by means of lead peroxide or a similarly suitable substance. This precaution is therefore also recommended, because as is well known the pyrite likewise occurring in clay demands on account of oxidation to sulphur dioxide the same precautionary measure.

SILICA REFRACTORIES.—W. J. Rees (*Chem. Tr. J.*, 64, 95, 1919). Based on tests in connection with the manufacture of silica bricks, a formula was established for the production of the standard brick now manufactured at the Dunes Works in France. Lime (generally added as milk of lime) furnished the most satisfactory bond, but china clay, aluminium sulphate, sodium silicate, and other substances had been used. As such additions reduce the refractoriness of the silica, the amount added should be only enough to give the burned bricks the necessary degree of strength. The lime exercised a bleaching action during the burning, combining with the iron oxide present, forming probably a colourless double silicate of calcium and iron. Colour was no criterion of the refractoriness of a brick, as a redder brick with low lime content might be more refractory than a whiter brick with higher lime. Evidence seemed to indicate that 4 or 5 per cent. of finely disseminated ferric oxide enabled bricks to withstand temperature variations better than the usual silica bricks. The texture (or physical structure) of a silica brick has a marked influence on its behaviour in use. A silica brick is found to consist of fragments of crystalline silica distributed in a matrix which was often glassy, and was probably composed mainly of calcium silicates, calcium-iron-silicates, and calcium-aluminium-silicates. Both size and shape of the silica fragments were important. The best results were given by bricks composed of angular fragments from $\frac{1}{4}$ inch downwards, with some extremely fine powder, so that (as in the case of concrete) voids should be as few as possible. Uniform texture is desirable, whether coarse or fine. Coarse-grained bricks would better resist sudden temperature changes, but the open texture allows flue dust, etc., to penetrate more readily. Fine-grained bricks would better resist the abrasive action of hot gases. Whether coarse or fine, silica bricks were particularly liable to splitting. Apparently bricks of uniform medium texture, with no fragments more than $\frac{1}{4}$ in. diameter, are on the whole most advantageous.

Very fortunately from a practical point of view, silica has no definite softening temperature, but there is a range of temperature within which it begins to lose shape and to flow. The softening range of silica is less affected by pressure than fireclay, so that in general silica bricks would carry load at

high temperatures better than aluminous firebricks. The collapse of silica bricks under load at high temperatures is rather a mechanical failure than a direct fusion collapse, and would be not gradual but somewhat abrupt. A satisfactory cement was produced by adding not more than 5 or 6 per cent. of fireclay to a highly siliceous rock. A good cement could be made by grinding finely the parts of used silica bricks which had not been fluxed in any way.

On the basis of existing knowledge, the following specification conditions were suggested for silica bricks intended for metallurgical use. An analysis of the bricks should be supplied, and bricks should contain not less than 94 per cent. of silica and not more than 2 per cent. of lime. The bricks should contain a satisfactory portion of extremely finely ground material, and no unduly large pieces, having regard to size of brick. The bricks should be evenly burned, and regular in texture, without holes or flaws. Test-pieces should not melt below cone 32 in oxidizing atmosphere, the furnace temperature being raised about 50° C. per five minutes. Test-pieces, after heating for two hours at cone 12, should not show more than 1 per cent. linear expansion on cooling, and the variation of any specified dimension should not be more than $\pm 2{\cdot}5$ per cent. When more precise knowledge is available as to the exact influence of iron oxide in a silica brick for metallurgical purposes, it might be desirable to modify the condition limiting the proportions of silica and lime.

THE MELTING POINTS OF CRISTOBALITE AND TRIDYMITE.—J. B. Ferguson and H. E. Merwin (*Amer. Jour. Sci.*, 46, 417, 1918). The previous determinations of the melting points of these minerals are not in good agreement amongst themselves and hence the authors have redetermined them, using a new type of "platinum" furnace built on the cascade principle. The resistance of the outer heater is platinum wire 0·8 mm. in diameter, wound on a helically grooved alundum tube. The inner heater consists of a wire, 80 Pt. 20 Rh., wound on a helically grooved magnesia tube, the insulating material both outside the outer tube and between the two tubes being magnesia. The outer furnace is raised to 1,450° C. before the current is passed through the wire of the inner tube. The inner tube can then be raised to 1,750° C. The melting point of cristobalite is determined as $1{,}710° \pm 10°$ C., and that of tridymite as $1{,}670° \pm 10°$ C. Quartz was found to convert to tridymite by the agency of "dry heat" at 1,350°, and tridymite similarly to cristobalite at 1,670°.

A.S.

III.—THE COMPOUNDING & PREPARATION OF CLAYS AND BODIES.

STONEWARE.—P. Eckert (*Tonind. Ztg.*, 41, 74, 1917). A brief description. The author states that he has obtained good trials with felspar, trachyte, pitchstone, or porphyry as fluxing material, and even with sandstone.

LIGHT SAND-LIME BRICKS.—E. Schleier (*Tonind. Ztg.*, 41, 98, 1917). An ordinary sand-lime brick $25 \times 12 \times 6{\cdot}5$ cms. weighs about 3·5 kg. Reference is made to lighter bricks of the same size whose average weight is 2·6, 1·8, and 1·4 kg. respectively.

HEAT IN THE PRODUCTION OF SAND-LIME BRICKS.—E. Schleier (*Tonind. Ztg.*, 41, 170, 1917). A discussion of the necessity for heat in making sand-lime bricks, with special reference to the utilization of the heat produced by slaking lime.

SILICA BRICKS WITH LIME BOND.—F. Janitz (*Tonind. Ztg.*, 41, 272, 1917). A brief account of the manufacture. The limit for lime is given as 2 per cent., and the firing temperature should be at least cone 18.

SAND-LIME BRICKS IN FRANCE.—E. Schleier (*Tonind. Ztg.*, 41, 291, 1917). A short account of the industry.

CHARGING TWO PRESSES.—A. Kr. (*Tonind. Ztg.*, 41, 595, 1917). A discussion of the question of filling two presses from one charge. The author once thought it possible to manage this with a single workman, but found it was necessary to have a second workman.

VERY LIGHT BRICKS.—(*Tonind. Ztg.* 41, 655, 1917). A short article in which are enumerated suitable purposes for the use of very light bricks (*Schwemmsteine*).

SLAKING LIME FOR SAND-LIME BRICKS.—L. G. and B. Kosmann (*Tonind. Ztg.*, 41, 697, 803, 1917). In order to prevent the occurrence of unslaked residues when slaking lumps of lime in the ordinary way, it is recommended to use warm water for the slaking. The presence of grains of unslaked lime in the bricks is thus avoided.

RAW DOLOMITE BRICKS.—B. K. (*Tonind. Ztg.*, 41, 821, 1917). A theoretical discussion respecting products of a certain definite composition, which is stated to approximate after expulsion of carbon dioxide to that of a burned cement.

FIREPROOF COOKING VESSELS.—K. G. (*Tonind. Ztg.*, 41, 899, 1917). A general discussion.

SIEVE ARRANGEMENT FOR CASTING POTS.—R. Seidel (*Ker. Rund.*, 25, 159, 1917). A movable sieve is made to slide in the top part of a can, so that the slip shall pass through the sieve to get to the lip of the can. The arrangement is figured.

SOME MACHINES FOR KERAMIC WORKS.—(*Ker. Rund.*, 25, 172, 180, 1917). A description of certain contrivances (some illustrated), such as a machine for washing crushed raw body materials (felspar, quartz, calcspar, dolomite, pitchers, etc.) before grinding, an arrangement for emptying the ashpits. Durable saggars can only be looked for if the fat clay (to be mixed with the saggar-clay) is well dried before being used. Otherwise clay nodules remain and by their greater contraction produce cracks in the saggars. Reference is also made to the necessity of removing impurities from "cuttings" before using the material again.

INSULATOR BODY AND GLAZE.—(*Ker. Rund.*, 25, 181, 185, 1917). A body is referred to consisting of 16 parts Löthain earthenware clay, 21 Dolau kaolin, 21 Börtewitz kaolin, 29 sand, 11 Norwegian felspar, and 2 dolomite. The glaze is made from 8 parts Dolau kaolin, 47 quartz, 35 felspar, and 10 dolomite. These are suggested as first trials. Another body consists of 500 parts Dolau kaolin, 400 sand, 98 felspar, and 2 calcspar (or whiting). The corresponding glaze consists of 23 parts quartz, 20 felspar, 20 glost pitchers, 6 biscuit pitchers, 8 dolomite, 3 calcspar (or whiting), 4 calcined Zettlitz kaolin and 6 raw Zettlitz kaolin. The body materials should be ground 12 to 15 hours, and the glaze materials 100 hours.

LOWERING THE FIRING TEMPERATURE OF PORCELAIN.—H. Stark (*Ker. Rund.*, 25, 205, 1917). It is suggested that the firing temperature of useful porcelain might be lowered through five stages from cone 14—15 (with a body consisting of 50 clay substance, 25 quartz, and 25 felspar) to cone 12 (with body consisting of 40 clay substance, 30·2 quartz, 28·5 felspar, and 1·3 calcspar). These bodies are alternatively made up of (*a*) 500 kaolin, 480 Tirschenreuth pegmatite, and 20 felspar, or (*b*) 448 kaolin, 338 Fürstenwald porcelain-sand, and 214 felspar, for the former, and (*a*) 400 kaolin, 580 Tirschenreuth pegmatite, 7 felspar, and 13 calcspar, or (*b*) 385 kaolin, 100 Fürstenwald porcelain-sand, 228 quartz, 274 felspar, and 13 calcspar for the latter.

It is pointed out that the less the proportion of clay substance the more sensitive the porcelain towards shocks and blows.

ENGLISH HARD PORCELAIN.—(*Ker. Rund.*, 25, 274, 1917). A brief reference to the second annual report of the Council for Scientific and Industrial Research.

NEW EVAPORATION FORMULA.—R. E. Horton (*Engineering News Record*, 78, 196, 1917). A discussion of the chief processes involved in evaporation and condensation. The author claims that his formula (or perhaps it should be formulæ, for there are several modifications adapted to varying conditions) gives results in better agreement with observed facts than other formulæ proposed. The want of agreement hitherto between observed evaporation and the amounts computed from other formulæ have arisen apparently from (1) improper application of the wind correction factor, (2) neglect of convection, and (3) failure to realise that the area factor is not constant for a given size of pan or evaporating surface, the ratio of the average evaporation rate over such a surface to the evaporation rate at the windward edge varying with each change of meterological conditions.

THE FILTER-PRESS.—D. R. Sperry (*Met. Chem. Eng.*, 18, 140, 1918). The filter-press (*a*) separates solids from liquids, and (*b*) washes, lixiviates or extracts. The first is performed by forcing or pumping the liquid containing the solids through a filter-base (usually cotton duck), thus retaining the solids in the cells or chambers of the filter-press. The liquid flows away, usually through cocks placed on each cell. The second process, called washing, consists in forcing water or some other liquid into the filter-press in such a way that it flows through the deposited solids, displacing therefrom the liquid contained in the pores which may later be recovered from the wash. Sometimes the wash water dissolves some desirable substance in the cake or solids, permitting its recovery later. The filter-press can also cause thorough precipitation of a substance contained in the liquid by reason of the intimate contact which the liquid necessarily makes with the solids, causing the precipitation, as it passes through the cake. The filter-press may separate solids from liquids, maintaining the process at some desired temperature. Thus a substance can be chilled and crystals filtered out, or a substance crystallizing at ordinary temperatures can be filtered hot in order to remove impurities and not crystals.

Some commercial uses of the filter-press are: (*a*) To make dull liquids clear and sparkling for appearance sake only (cider, near-beer, liquid soaps, etc.). (*b*) To remove substances from liquids for re-use or which would injure the product if allowed to remain (fuller's earth or bleach from lard, nickel from hydrolysed vegetable oils, lime from sugar juices, etc.) (*c*) To separate a valuable liquid from a mass and then dissolve out or lixiviate some valuable substance contained in the solids (treatment of cyanide slime in gold metallurgy. (*d*) To separate a valuable mass from a liquid and then lixiviate the valuable portion of the mass, the liquid being used solely as a conveyor for the mass (lixiviating ground quartz in gold metallurgy after it has been deposited in the press by means of water). (*e*) To reduce a muddy mass to a more convenient form (sewage sludge, china clay, etc.). (*f*) To save fuel in evaporation by removing the greater part of the moisture in the filter-press (manufacture of lithopone, white lead, etc.) (*g*) To aid precipitation by mixing a substance causing precipitation with the liquid and pumping the mixture in a filter-press (gold metallurgy, where zinc-dust is added to cyanide solution and is fed into a filter-press, the intimate contact of the cyanide solution causing gold to precipitate as it flows through the cake of zinc-dust.) (*h*) To crystallize out a substance which at ordinary temperature is liquid, by filtering in a refrigerated filter-press at which temperature crystals form (filtering certain oils). (*i*) To clarify a substance which at ordinary temperature is crystalline, by filtering in a steam-jacketed filter-press at a temperature too high for crystals to form (Glauber's salts, where hydroxide of iron is removed). (*j*) To separate a solid from an unstable liquid in a closed-discharge filter-press

where the liquid does not come in contact with the atmosphere (certain varnishes and in cases where the liquid evaporates easily, as alcohol).

Advantages of the filter-press over other forms of filter are : (*a*) Greater filtering area per unit of floor space. (*b*) Lower cost per square foot of filtering area. (*c*) Lower cost of maintenance and repairs. (*d*) Lower operating expense because no skilled labour required.

One of the simplest forms of filter-press consists of a screw-press supported on legs and a number of plates resting on the bars of the press and held together between the heads, minor attachments being a row of cocks and a gutter. It should be understood that a filter-press is a press which is employed to hold together the component parts of a filter, and not (as is commonly supposed) to press the solids within the filter.

An illustrated description is given of the construction and manner of operating filter-presses, and reference is made to a case where filter-presses containing 40 plates (or trays) have been opened, the solids removed, and closed again in an average time of 15 minutes, two common labourers performing the operation with ease.

GRAPHITE CRUCIBLES.—E. Rietz (*Pat. J.*, No. 1,512, 1918). Pat. No. 111,152, Nov. 14th, 1916. A graphite crucible contains, besides graphite and clay, sand, etc., 5 to 40 per cent. of rare earth compounds. Natural or artificial oxide or silicate or other salt of zirconium may be used. Suitable mixtures are 35 parts zircon earth, 40 graphite, and 25 clay, or 10 parts zircon earth, 70 graphite, and 20 clay. The crucible made from the ground mixture with a flux or the like is baked at about 1,000° C.

REFRACTORY BRICKS, etc.—A. Reynolds (*Pat. J.*, No. 1,513, 1918). Pat. No. 111,355, Dec. 4th, 1916. Coherence is imparted to the bricks, etc., by subjecting the working surface or surfaces, after the usual burning, to a temperature sufficiently high to produce incipient fusion. Bricks are bedded in the floor of a furnace with the working surface uppermost, and the spaces between them are filled with a ramming of highly refractory material such as chromite, plumbago, or ground carbon and tar.

SEPARATING COAL, ORES, etc.—J. M. Draper and Rhondda Engineering and Mining Co. (*Pat. J.*, No. 1,516, 1918). Pat. No. 111,826, Oct. 5th, 1917. Addition to 1,849/15. See TRANS., 17, 213, 1918.

ZINC EXTRACTION.—D. B. Jones and C. H. Fulton (*Pat. J.*, No. 1,523, 1918). Pats. Nos. 112,923 and 112,924, Aug. 10th, 1917. Blue powder, zinc dross or ashes, or material containing metallic zinc is moulded into briquettes that will maintain their form and volume during distillation, and these briquettes are distilled in any convenient way. The second of the two patents relates to similar treatment of ores, etc.

ALUMINIUM CARBIDE. ELECTRODE FURNACES.—Standard Oil Co. and others (*Pat. J.*, No. 1,523, 1918). Pat. No. 112,929, Nov. 26th, 1917. Aluminium carbide is made by passing current through a carbon or graphite core embedded in a mixture of alumina with excess of carbon.

ZIRCONIUM OXIDE AND SALTS.—Imperial Trust, R. T. Glazebrook, W. Rosenhain, and E. H. Rodd (*Pat. J.*, No. 1,523, 1918). Pat. No. 112,973, Jan. 29th, 1917. Basic zirconium sulphate is obtained by adding to an acid solution containing zirconium sulphate (and preferably hydrochloric acid) ammonia or caustic soda until a permanent precipitate begins to form, and then allowing precipitation to continue by itself. The sulphate solution may be made by heating together crude zirconia, fluorspar, and sulphuric acid, adding water, separating the calcium sulphate, and adding some hydrochloric acid. The basic sulphate can be converted into oxide by ignition, or into hydroxide by suspending in water and agitating with ammonia. The basic sulphate may be made in purer condition from the hydroxide.

LIGHT SILICA.—General Electric Co. (*Pat. J.*, No. 1,528, 1918). Pat. No. 113,769, Nov. 9th, 1917. Silica in a light voluminous form suitable as an electric fuse filler, as described in Specification 8,821/14, is made by adding a solution of an alkaline silicate to a solution of an ammonium salt such as the chloride, bromide, nitrate, sulphate, or acetate, boiling to decompose the precipitated ammonium silicate, separating the silica, washing and calcining at 100—150° C., and finally sifting through a 20—40 mesh sieve. Alternatively, the ammonium silicate may be filtered off, washed, and heated to about 150° C.

POROUS HEAT-INSULATING COMPOSITION.—H. S. Ashenhurst (*Pat. J.*, No. 1,528, 1918). Pat. No. 113,810, March 2nd, 1917. A cellular composition is made by mixing refractory material such as comminuted asbestos, mica, kieselguhr, and calcium sulphate, with substances (for instance calcium carbonate and aluminium or other sulphates) which generate gas and form a product which hydraulically sets. The materials may be kept mixed in a dry condition. In some cases it is necessary to add dextrine, glue, gelatine, etc. In an example, 32 parts of an inert silicate, 8 parts of sulphate, and 1 part of carbonate are employed, and (to accelerate hardening) plaster of Paris may be added. The product, which has a specific gravity of less than 0·4 when asbestos is used, may be employed for heat insulation, is fireproof and sound-deadening, and may be moulded in situ or otherwise for making walls, floors, and ceiling, around furnaces or steam pipes.

POROUS HEAT-INSULATING COMPOSITION.—N. Ito (*Pat. J.*, No. 1,536, 1918). Pat. No. 115,163, Aug. 8th, 1917. A porous heat-insulating material is made from a well-kneaded mixture of calcium sulphate, sodium bicarbonate, kieselguhr, and asbestos or other fibrous substance. Carbon dioxide is liberated and renders the product porous. In an example, 100 parts of a solution of calcium bicarbonate and 4·7 parts of sodium bicarbonate are mixed with a mixture consisting of 50 parts kieselguhr, 20 parts of asbestos, 40 parts of magnesium carbonate, and 40 parts of anhydrous calcium sulphate. A small percentage of calcium hydrate may be added. The material may be moulded, or may be directly applied to boilers, steam pipes, or brine pipes of refrigerators.

ABRASIVES.—Norton Co., L. E. Saunders, and R. H. White (*Pat. J.*, No. 1,529, 1918). Pat. No. 113,957, Feb. 7th, 1918. A crystalline aluminous abrasive, prepared by fusion in an electric furnace, is derived from raw materials containing alumina and iron oxide but substantially free from silica and titanium oxide. As raw materials may be used the alumina prepared from natural aluminium sulphate, the slags resulting from thermite smelting and welding processes, and products obtained from clay by means of hydrofluoric acid. The product may contain 1—15 per cent. of ferric oxide. The prior manufacture of an abrasive consisting of alumina substantially free from fluxing impurities is referred to.

ABRASIVES, etc.—Norton Co., L. E. Saunders and R. H. White (*Pat. J.*, No. 1,529, 1918). Pats. Nos. 113,958, 113,959, and 113,960, Feb. 7th, 1918. The first, *which has also refractory properties*, is prepared by fusing together in an electric furnace alumina and zirconia, in various proportions and with or without other oxides. The second is prepared from calcined bauxite and zirconia or zircon. The third contains β-alumina (a crystalline form differing from the natural corundum, etc.), and is prepared by fusing alumina in an electric furnace in the presence of varying proportions of converting agents (such as sodium carbonate, aluminate, sulphate, and hydrate, etc.)

ALUMINA.—Mineral Products Corporation and J. W. Hornsey (*Pat. J.*, No. 1,551, 1918). Pat. No. 118,063, Feb. 27th, 1918. Impure alumina resulting from the calcination and leaching of alunite is purified by mixing it in a finely divided condition with water to form a pulp, and subjecting the pulp to a flotation process in any suitable apparatus such as a Callow, Hoover, or Janney cell, with or without the use of a frothing agent, such as oleic acid.

SILICA BRICKS.—Soc. Anon. des Produits Refractaires de L'Ouest (*Pat. J.*, No. 1,551, 1918). Pat. No. 118,116, Aug. 6th, 1918. Silica bricks are made from any quartz or quartzite containing an average of 95 per cent. silica. After disintegrating or after cooling, the material is subjected to a first crushing and part then reduced to a fine flour by a further crushing. Suitable proportions of the two crushings are mixed together with a binder such as lime, moulded, and burned.

POTASSIUM OR SODIUM ALUMINATE OR CARBONATE; ALUMINA.—E. E. Dutt and P. C. Dutt (*Pat. J.*, No. 1,551, 1918). Pat. Nos. 118,155 and 118,156, Aug. 18th, 1917. A mixture of calcined bauxite or like aluminous substance with potassium or sodium chloride, calcium hydrate, and carbon is heated to dull redness in a muffle and submitted to the action of arsenic trioxide vapour. The charge from the muffle is lixiviated with water, yielding solution of potassium or sodium aluminate, which may be evaporated to dryness or may be treated with carbon dioxide to yield a precipitate of aluminium hydroxide and a solution of potassium or sodium carbonate.

ALUMINIUM CHLORIDE; ALUMINA.—R. Welford (*Pat. J.*, No. 1,552, 1918). Pat. No. 118,312, Aug. 18th, 1917. Clay, bauxite, and the like, which may be dried at a low temperature, is heated with hydrochloric acid to dissolve the aluminium. The solution separated from the residues may be purified, and is evaporated to dryness, the crystals being then further heated with steam to produce alumina, the hydrochloric acid expelled being recovered.

ABRASIVES.—Norton Co., L. E. Saunders and R. H. White (*Pat. J.*, No. 1,554, 1918). Pat. Nos. 118,591 and 118,592, Feb. 7th, 1918. An aluminous abrasive having a weak grain is obtained by fusing an aluminous material (as bauxite) with a small proportion of the substance capable of existing in the vapour phase at the temperature at which the charge solidifies. The substances used comprise alkali metal compounds, such as sodium carbonate, sulphate, hydroxide or aluminate, aluminium fluoride, and zinc powder. Soda-ash (2 to 3 per cent.) is preferred.

ALUMINIUM COMPOUNDS.—A Christiania Firm (*Pat. J.*, No. 1,561, 1918). Pat. No. 120,035, July 23rd, 1918. Aluminium compounds are prepared from clay, argillite, or similar minerals by treatment with acids in an autoclave under pressure. When nitric acid is used, the pressure is stated to prevent dissociation at the temperature employed. The silicic acid is said to be obtained in a grainy state, and readily separable by filtration.

ALUMINA.—Norton Co., L. E. Saunders and R. H. White (*Pat. J.*, No. 1,554, 1918). Pat. Nos. 118,605 and 118,606, July 11th, 1918. Alumina is prepared in fused condition from crude materials such as bauxite and clay by fusing the material with excess of carbon in an electric furnace. Precautions are described.

DENTAL CEMENTS.—W. S. Crowell (*Pat. J.*, No. 1,554, 1918). Pat. Nos. 118,701 and 118,702, Sept. 26th, 1917. Relates to the incorporation with dental cements of substances for preventing the recurrence of decay.

SIFTING, etc.—A. C. Harrison (*Pat. J.*, No. 1,555, 1918). Pat. No. 118,800, Mar. 5th, 1918. A machine for sifting potters' slip, powdered substances, etc. consists of a frame carrying three detachable lawn frames or sieves placed one above another and a collecting box below the lowermost sieve, rocked on a shaft arranged longitudinally and in the centre of the machine by means of a link and crank, etc. Springs mounted on a fixed structure engage with the frame, and tend to keep it in the vertical position. The detachable sieve frames are fitted with inclined sieves, provided with inclined partitions, to convey the material passing through one sieve to the upper end of the next sieve, and are open at their lower ends. In a modification, the rocking frame is suspended from an overhead shaft carried by a beam.

WASHING COAL, ORES, etc.—T. M. Chance (*Pat. J.*, No. 1,555, 1918). Pat. No. 119,038, Sept. 9th, 1918. Materials of different specific gravities are washed, concentrated, or separated by means of an agitated fluid mixture of a liquid such as water and a granular solid such as sand surmounted by a body of liquid such as water.

CASTING CLAYWARE.—C. W. Thomas (*Pat. J.*, No. 1,563, 1918). Pat. No. 120,318, Feb. 9th, 1918. Moulds for casting clayware from slip are provided with hollow walls through which heated air or other drying medium is circulated to expedite the casting operation. Preferably the inner wall portions are porous and the outer portions non-porous.

CARBON ELECTRODES FOR FURNACES.—J. A. Holden (*Foundry Trade J.*, 20, 537, 1918). Graphite electrodes are invariably used in furnaces of large capacity, and to some extent also in small furnaces. Compared with those of amorphous carbon their electrical conductivity is about four times as great. The writer has used Acheson graphite electrodes $5\frac{1}{8}$ inch in diameter to carry a current of 4,500 amps., and although the joint became visibly hot no serious inconvenience was experienced. The use of graphite renders it possible to adopt a light construction for the holders, together with a corresponding light design for the framework of the hoisting gear. As graphite can be easily machined it is possible to use accurately cut screw-joints and avoid an accumulation of stub ends. Graphite electrodes have only about half the tensile strength of amorphous carbon electrodes, so careful manipulation is essential to keep down the number of breakages. Thus in joining, it is necessary to have the two electrodes in perfect alignment, and not to screw them very tightly together. The successful making of joints is learned with a little practice, and a satisfactory joint is not uncommonly made in three or four minutes. The low electrical conductivity of amorphous carbon is in some respects a decided advantage, as the large electrodes act as powerful insulators to the furnace roof, the life of which is much longer than when graphite electrodes are used. In the author's experience the economy amounts to about 33 per cent. of the roof cost.

Unlike graphite electrodes, a paste is necessary for joining amorphous carbon electrodes, which are difficult to machine. The threads, both in the electrode and on the plug, are made by moulding in a die, and are consequently not so accurate as are cut threads. The joining paste is used to produce intimate contact, for arcing would result if all interstices were not filled with a good conductor. An excellent material for making the paste is the best quality Ceylon plumbago ground extremely fine, and mixed with hot anhydrous tar (ordinary gasworks tar is useless) to the consistency of treacle. A suitable jointing paste is sold under the name of "Jungo." As the life of an electrode is largely determined by the soundness of the joint, careful attention to this is profitable. Several screw plugs are tried, and one which grips the thread is chosen. The paste is next heated to about 90° C., and smeared over the lower half of the plug, which is then screwed home. Before the new electrode is attached, the projecting half of the plug is also coated lightly with the hot paste. In order to prevent slipping in the holder, the electrodes are made with a slight taper, and to secure a correct joint the diameter must be measured beforehand with a pair of calipers.

Damp and wet are a prolific source of cracked electrodes, and if the top of an annealing or drying stove can be secured for storage it should be utilized. The electrode consumption has an important bearing on the cost of production. Some electrodes burn very thin, tapering down to a fine point, and are then said to "point" badly. Such electrodes prove troublesome because they invariably break off, and the delay in removing the fractured pieces causes considerable loss.

EXCHANGE OF BASES IN SILICATES.—E. Ramann and A. Spengel (*Zeits. anorg. Chem.*, 95, 115, 1916). Relates to the exchange of alkalies and ammonia in hydrated alumina alkali silicates (permutites). Sodium permutite

is purified by treatment with a 10 per cent. solution of sodium chloride until calcium is no longer extracted. In the presence of small quantities of calcium carbonate, purification is effected more rapidly by treating with 10 per cent. ammonium nitrate, followed by reconversion of the ammonium permutite into sodium permutite. The granular permutite is freed from small particles, and the reacting solution is run through it at the rate of 50 c.c. per hour. In this way complete equilibrium is reached.

Sodium permutite yields the corresponding potassium permutite with potassium chloride and potassium sulphate, and the ammonium permutite is also completely converted into potassium permutite. The total concentration of the solutions does not affect the composition of the final product, nor does the nature of the alkali in the original permutite. With mixed solutions of different salts, the resulting composition indicates that the reaction is entirely ionic, and is independent of the nature of the anion.

RECOVERY OF POTASSIUM AND ALUMINIUM SALTS FROM MINERAL SILICATES.—J. C. W. Frazer, W. W. Holland, and E. Miller (*J. Ind. Eng. Chem.*, 9, 935, 1917). Finely ground felspar is mixed with 80 per cent. of its weight of potassium hydroxide (or an equivalent quantity of sodium hydroxide), and a little water, the mixture is dried and heated for an hour at 300° C., and afterwards treated with water and filtered. The alkali used may be recovered from the filtrate. The insoluble portion, which has the composition $KAlSi_2O_6$, is then treated with hydrochloric acid equivalent in amount to the potassium content, when potassium chloride is formed. The insoluble aluminium silicate remaining is readily decomposed by sulphuric acid, aluminium sulphate being formed.

FORMATION OF TRICALCIUM ALUMINATE.—E. D. Campbell (*J. Ind. Eng. Chem.*, 9, 943, 1917). Tricalcium aluminate seems to be formed best by keeping the compound $5CaO.3Al_2O_3$ in prolonged contact with lime just above 1,395° C. but below 1,455° C. (the melting points of the eutectic solution of lime and of pure $5CaO.3Al_2O_3$ respectively). The binary systems of lime and alumina with over 47·8 per cent. of lime should be regarded as a solution of lime in the compound $5CaO.3Al_2O_3$. Tricalcium aluminate may be regarded as a metastable saturated solid solution of lime in $5CaO.3Al_2O_3$, or as $5CaO.3Al_2O_3$ with 4 molecules of CaO crystallization, rather than as a stable phase in the strict sense of the word.

GLASS-LIKE PORCELAIN.—(*Deut. Töpf.-Zieg.-Ztg.*, 48, 128, 1917). A South German firm has succeeded in producing porcelain objects, especially crucibles, with which it is possible in separate places, with the oxy-hydrogen blowpipe, to melt holes without cracking the pieces. Porcelain parts can be melted on to one another and worked just as with glass. According to this, holes 3 to 4 mm. across at the upper margin and more in the bottom in small porcelain tubes can be fastened by melting. This result depends on the absolute equality of the coefficients of expansion of body, glaze, and glass melted from both. This agreement determines also the great stability as regards temperature and the breaking strength of the new kind of porcelain in laboratory use. For the bursting of porcelain vessels with temperature changes is nearly always to be traced to the releasing of strains between body and glaze, which could be constituted because the coefficient of expansion was different for the two materials. But the latter possibility is quite eliminated with the new kind of porcelain. After further trials it was found possible to blow porcelain melted to glass exactly as in working with glass.

THE PRACTICAL BRICKMAKER.—(*Deut. Töpf.-Zieg.-Ztg.*, 48, 3, 9, 34, 41, 50, 82, 113, 137, 154, 169, 185, 201, 217, 241, 257, 266, 281, 289, 305, 322, 338, 354, 361, 369, 1917). A series of articles in continuation and completion of others which appeared earlier. The present series have reference to machine brickworks, the subject specially discussed including the clay materials, the making of building bricks, hollow bricks, stretchers and bonders, drain-pipes, monk and nun bricks, shaped bricks, etc., drying arrangements, stacking of

unfired pieces, kilns and firing, the carrying out of the burned bricks, glazing of bricks (a number of mixtures for leadless and lead glazes, white and coloured, being quoted on pp. 266—8), engobes (mixtures, pp. 281—2, white and coloured), tarring of roofing tiles, annular kiln, intermittent kilns, machinery (including presses, etc.), written work of the master (wages, etc.), and other points of interest.

SECURING GLAZED CLAYWARES AGAINST CRAZING.—H. Harkort (*Deut. Töpf.-Zieg.-Ztg.*, 48, 163, 1917). Relates to Harkort's German Patent No. 297,719. The addition of chalk and dolomite to ceramic (especially earthenware) bodies results in the first place in securing these masses against crazing. It is well known that body compositions which show crazing, by addition of chalk with otherwise the same composition and firing treatment are obtained free from crazing. Investigations then have proved that such bodies mixed with chalk are to be increased in their security against crazing by a small rise of temperature in the glost firing, whereas in chalkless bodies this is not or only in small measure the case, that is, by addition of chalk the reacting power of the body with the glaze is increased. These improvements through addition of chalk stand against the diminution of strength, which arises to a considerable extent with somewhat higher additions of chalk.

The new process avoids these latter evils because it introduces soluble salts into the mass during the preparation, thus increasing the reacting power of the body with the glaze. Salts of calcium, but also those of other alkaline earths and of magnesium, come particularly into consideration. During the drying of the shaped pieces the salt travels to the surface of the latter, and separates out there, where it is later enabled to enter into reaction with the glaze and to form a balancing intermediate layer, whilst the salt is withdrawn from the core and thus it completely retains its strength. These intermediate layers spontaneously form a gradual transition from body to glaze. Calcium and magnesium chlorides are mentioned as being most suitable in many cases, but in certain instances salts of organic acids are to be preferred because they are easily decomposed. The quantity of salt to be added depends largely on the difference in expansion between body and glaze.

IV.—SHAPING AND MOULDING. DRYING.

PREVENTION OF FIRE BLISTERS.—C. Schneider and L. H. (*Tonind. Ztg.*, 41, 313, 516, 1917). The question is discussed briefly with special reference to stoneware tubes, the fault being attributed to certain circumstances connected with the making, drying and firing. L. H., on p. 516, comments critically on some of Schneider's statements.

EFFLORESCENCES.—H. Pallus and K. Jakob (*Tonind. Ztg.*, 41, 155, 283, 401, 1917). A brief discussion of these occurrences in bricks. Pallus states that the best means of destroying the salts is a sharp fire. Jakob's contribution (p. 283) is a critical review, to which Pallus replies.

DRYING PLASTER MOULDS.—M. M. (*Ker. Rund.*, 25, 42, 1917). A general discussion.

DEFECTS APPEARING DURING MANUFACTURE OF PORCELAIN.—A. Heber (*Ker. Rund.*, 25, 53, 1917). A brief survey of the troubles which may arise at various stages.

CUTTING UP AND STORING CLAY MODELS.—E. Motschmann (*Ker. Rund.*, 25, 123, 1917). A short discussion of the points needing consideration for different classes of models.

DRYING APPARATUS.—A. Hofman (*Pat. J.*, No. 1,502, 1917). Pat. No. 109,267, Aug. 23rd, 1916. The material passes backwards and forwards from above to below in a drying chamber. Heated gases, after use for heating inflowing air, are directed on to the material at certain places.

PRESSES AND PUMPS.—R. W. Easton (*Pat. J.*, No. 1,504, 1917). Pat. No. 109,663, Sept. 25th, 1916. Apparatus which may be used as a press or pump, comprises two similar intermeshing screws working in a casing which may be heated externally. The pump may be used for air or other gases, steam, liquids, semi-liquids with solids, or semi-solids in suspension such as sewage, china clay, gravel, etc. The press may be used with briquetting plant, etc.

DRYING, MIXING AND GRINDING COLOURS, etc.—G. Calvert (*Pat. J.*, 1,505, 1917). Pat. No. 109,838, Sept. 26th, 1916. Relates to apparatus for drying, mixing, and grinding colours, chemicals, etc., and of the kind comprising a vessel rotating in bearings in the walls of a heated oven and containing loose grinding-balls. The vessel is formed independently of its trunnions and detachably clamped thereto.

CASTING POTTERY, etc.—B. J. Allen and R. Y. Ames (*Pat. J.*, No. 1,509, 1917). Pat. No. 110,649, Dec. 11th, 1916. Relates to the casting of articles from slip mixtures in plaster, porous pottery, or other absorbent moulds, and consists in applying a vacuum to augment deposition. The moulds may be encased wholly or partly by a vacuum jacket. See paper in TRANS, 16, 134, 1917.

CASTING POTTERY.—B. J. Allen and R. Y. Ames (*Pat. J.*, No. 1,515, 1918). Pat. No. 111,643, July 14th ,1917. Addition to 110,649. Consists in the application of pressure to the slip mixture in addition to the vacuum.

MOULDING. ELECTRIC ENDOSMOSE.—B. J. Allen (*Pat. J.*, No. 1,515, 1918). Pat. No. 111,762, Feb. 15th, 1917. Articles of clay, plumbago, silica, or the like, are made by deposition from suspensions by electric endosmose on plaster or other porous moulds. The porosity and thickness of the deposits may be varied.

MOULDING. ELECTRIC ENDOSMOSE.—B. J. Allen (*Pat. J.*, No. 1,515, 1918). Pat. No. 111,775, March 3rd, 1917. Addition to 111,762. Articles of clay, plumbago, silica, alumina, etc., are made by deposition from suspensions on metal moulds by electric endosmose. Crucibles, cores, tubes, muffles, etc., may be made.

BRICK-MOULDING MACHINES.—N. Brooke and F. Rogers (*Pat. J.*, No. 1,509, 1917). Pat. No. 110,625, Nov. 4th, 1916. Relates to machines for moulding silica and like bricks, and consists in the employment of a loose bottom plate within a rigid mould, which plate is ejected with the brick and serves as a support during its transference to the drying chamber. A second plate may be employed at the top of the mould.

ELECTRIC INSULATORS.—G. V. Twiss, and Bullers, Ltd. (*Pat. J.*, No. 1,515, 1918). Pat. No. 111,624, April 16th, 1917. Refers to double-flanged insulators of the " Hewlett " type.

ACID-PROOF VESSELS.—W. Hassall (*Pat. J.*, No. 1,519, 1918). Pat. No. 112,330, Jan. 19th, 1917. Acid-proof pots or vessels of stoneware, enamelled fireclay, earthenware, etc., are bound, after firing, with hoop-iron, wire, or other protecting bands provided or connected with resilient means, which permit the vessels and the bands to expand together to the same extent.

MOULDING MACHINES.—R. E. Larson (*Pat. J.*, 1,522, 1918). Pat. No. 112,724, May 31st, 1917. Relates to machines for moulding concrete, clay, etc., of the type in which the cores and moulds are moved simultaneously in opposite

directions to release the moulded products. The cores and moulds are connected by links to disks mounted upon a common shaft operable by a lever.

BRICK, ETC., PRESSES.—J. W. Craven (*Pat. J.*, No. 1,522, 1918). Pat. No. 112,834, Feb. 6th, 1917. Relates to presses in which the lower mould member is yieldingly supported by a hydraulic ram working in a cylinder connected to a second cylinder fitted with a plunger acted upon by a spring, etc.

ELECTRIC INSULATORS.—T. Taylor (*Pat. J.*, No. 1,523, 1918). Pat. No. 112,911, Oct. 1st, 1917. Leading-in insulators for wires of telephones, etc., of the type described in Specification 2,959/07 are provided with a plain disk cap for closing the cavity containing the sealing and insulating medium. Caps with flanges or otherwise modified are sometimes used instead of a plain disk.

LAVATORY BASINS.—E. Johns & Co., and E. R. Corn (*Pat. J.*, No. 1,537, 1918). Pat. No. 115,310, June 1st, 1917. An outlet fitting for lavatory basins.

SIFTING, etc.—A. Schar (*Pat. J.*, No. 1,542). Pat. No. 116,693, April 22nd, 1918. The arrangement provides that two boxes while moving in circular paths move together and apart parallel to themselves. The invention may be embodied in a freely oscillating plansifter.

MOULDING BRICKS.—N. Brooke and F. Rodgers (*Pat. J.*, No. 1,545, 1918). Pat. No. 117,149, July 19th, 1917. A resilient support for the bottom plunger of a brick machine, particularly adapted for the repressing of silica bricks, comprises a platform supported by (three) powerful springs situated within a casing, and free to move vertically upon bolts fixed in the bed, the plunger block being secured to the platform by bolts and supporting the plunger through interposed springs which give the following-up motion upon the withdrawal of the top plunger. The bricks are moulded in a press of the type having the mould provided with apertures for the escape of excess material and are then repressed.

DRYING AND HEATING APPARATUS.—F. Moore (*Pat. J.*, No. 1,553, 1918). Pat. No. 118,394, March 19th, 1918. Relates to apparatus for drying or heating a series of articles in succession after being coated by dipping, etc. A rotary table is provided (at outer edge) with an annular grid to receive the articles, placed on trays, which are carried (during rotation of the table) through an oven heated by steam pipe, etc., which runs through the oven (or stove).

MOULDING INSULATORS, etc.—H. O. Busch-Jensen (*Pat. J.*, No. 1,553, 1918). Pat. No. 118,563, March 12th, 1918. Relates to dies of the kind in which an intermediate die member is rigidly connected to the plunger and is embraced by spring-actuated end-members.

MOULDING ROOFING TILES, etc.—O. J. Oakley and E. C. Hughes (*Pat. J.*, No. 1,555, 1918). Pat. No. 118,793, Feb. 25th, 1918. Relates to a machine for moulding roofing tiles, etc.

MOULDING PIPES, etc.—R. H. Bicknell (*Pat. J.*, No. 1,555, 1918). Pat. No. 118,803, Aug. 15th, 1917. Pipes, etc., are formed by projecting cementitious material against the interior of a rotating mould by means of an air blast. The moulds are supported upon revoluble horizontal plates driven from a shaft through disconnectible bevel-gearing, and the material is fed from hoppers through worm-driven measuring-devices to pipes terminating in spraying-cores

REFRACTORY SUBSTANCES.—H. E. Mason and A. Couper (*Pat. J.*, No. 1,556, 1918). Pat. No. 119,101, Sept. 27th, 1917. In the manufacture of refractory magnesite bricks, a salt or salts of boric and/or perboric acid in conjunction with one or more of the following fluxing agents: basic slag, iron

oxide, iron ore, metallic iron or iron slag, is incorporated with a mixing of calcined or raw magnesite and water. The mixture is formed into bricks and fired. Alternatively the fluxing agent or agents and borate, etc., are mixed, shaped into bricks, calcined, and ground into powder before being mixed with the calcined magnesite. The average proportions in 100 parts of mixing are about one part of borate, etc., to about 6 parts of each or any or all of the fluxing agents named.

ELECTRIC INSULATORS.—H. R. Lamb (*Pat. J.*, No. 1,558, 1918). Pat. No. 119,382, Jan. 31st, 1918. Porcelain or earthenware insulators are formed with a recess for receiving the head of the suspension bolt, a groove or the like for mounting the insulator on the supporting means, and an outwardly flaring skirt.

ELECTRIC INSULATORS.—Taylor, Tunnicliff, & Co., and E. D. M. Scrivener (*Pat. J.*, No. 1,560, 1918). Pat. No. 119,795, Feb. 13th, 1918. An insulator, particularly for use in atmospheres charged with salt or other driving spray, comprises an outer shed, an inner shed, and a base disk or closure attached to the outer shed and adapted almost to close the lower open end of the insulator. The outer and inner sheds are preferably two separable parts, but they may be integral.

ELECTRIC INSULATORS.—G. V. Twiss and Bullers, Ltd. (*Pat. J.*, No. 1,560, 1918). Pat. No. 119,829, May 3rd, 1918. In multiple-unit pillar insulators, each unit is formed with a cap having a flange substantially level with the top of the cap, whereby any unit can be removed without disturbing the other units

ELECTRIC INSULATORS.—Soc. Metallurgica Italiana (*Pat. J.*, No. 1,563, 1918). Pat. No. 120,336, April 9th, 1918. In order to fix metallic sleeves on the inside or outside of glass, porcelain, or like electric insulators, the sleeves are soldered to a thin cup or ring of copper or other suitable metal fitted by mechanical pressure on to a layer of elastic material. Annular ribs are formed on one surface of the sleeves, the other surface being screw-threaded.

BRICK-MAKING MACHINES.—O. J. Moussette (*Pat. J.*, No. 1,561, 1918). Pat. No. 119,918, Oct. 24th, 1917. Relates to rotary mould table machines.

DOLOMITE BRICKS, etc.—A. Rollason (*Pat. J.*, No. 1,524, 1918). Pat. No. 113,199, May 3rd, 1917. Bricks, blocks, etc., are made by roasting dolomite at 1,050—1,350° C. until it becomes semi-fused, hard, granular, and non-absorbent, then crushing and mixing with about 1—5 per cent. of finely crushed dry silica or siliceous clay. The thoroughly mixed mass is damped with water or other liquid, or is mixed with hot dehydrated tar, moulded, and heated in a kiln to the fusing point of the silica or siliceous clay. The temperature is then raised and maintained slightly above that of fusion, then lowered below the fusion point, and finally slowly raised and maintained at the highest temperature attainable in the kiln.

MOULDING PIERCED ARTICLES.—Taylor, Tunnicliff & Co., and P. Cooper (*Pat. J.*, No. 1,525, 1918). Pat. No. 113,233, Aug. 31st, 1917. Relates more particularly to porcelain bead insulators adapted to be strung upon a bare wire or conductor.

BRIQUETTING PRESSES.—T. Gilmore and General Briquetting Co. (*Pat. J.*, No. 1,525, 1918). Pat. No. 113,279, Feb. 5th, 1918. Material such as metal or mineral "fines," etc., is pressed into briquettes by means of a ram which forces it from a charging chamber into a mould and compresses it against a plate. After pressing, the plate is withdrawn, and the briquette pushed forward by the ram to a discharge channel.

MOULDING POTTERY.—W. Hudson, G. E. Barlow, and J. V. Chapman (*Pat. J.* No. 1,528, 1918). Pat. No. 113,749, Aug. 30th, 1917. Cups, mugs,

basins, etc., are formed with shaped edges by the use of a profile furnished with a projecting curved portion adapted to extend over the top of the clay liner. The mould has an annular groove to accommodate the projecting part of the tool and to receive surplus material.

POTTERY.—W. Hudson, G. E. Barlow, J. V. Chapman, and J. Houghton (*Pat. J.*, No. 1,536, 1918). Pat. No. 115,174, Aug. 30th, 1917. A machine for producing clay liners for the formation of cups, mugs, basins, etc. Comprises a revoluble spreader upon which a ball of clay is shaped by an interior profile mounted upon an arm pivoted to a standard and operated automatically through a link, and exterior shaping blocks or plates mounted upon a pair of pivoted arms which are moved towards each other upon the descent of the profile and are separated upon its withdrawal.

MOULDING BRICKS,etc.—T. Longstaff and A. D. Glairns (*Pat. J.*, No. 1,533, 1918). Pat. No. 114,676, April 18th, 1917. A machine for moulding silica, plastic, ganister, fireclay, etc., bricks or briquettes. Comprises a vertical pugmill provided with a central shaft carrying adjustable wipers from which material passes through an opening into a mould carried by reciprocating bars, which move the filled mould between the filling and discharging positions. In the latter position the mould is lifted by grooved lifting-bars whilst the brick is pressed and held down upon a pallet by means of a plate operated through levers from cams on a shaft.

MOULDING PLASTIC SUBSTANCES.—Taylor, Tunnicliff & Co., and P. Cooper (*Pat. J.*, No. 1,534, 1918). Pat. No. 114,922, May 17th, 1917). In presses having sliding, grooving or recessing members, these are operated by means of a rotary member furnished with two grooves engaging pivoted blocks. The grooves may be circular, straight, or curved. The rotary member may be provided with ribs instead of grooves. The mould is constituted by a central aperture in the rotary member, or a non-rotary sleeve secured by screws may be provided.

ADVANTAGES OF DRY PRESSING FOR THE CLAY INDUSTRIES.—A. E. Buch (*Deut. Töpf.-Zieg.-Ztg.*, 48, 81, 1917). It is claimed that the dry pressing process has distinct advantages in the case of two classes of clay products: 1. Products used in roads and pavements. 2. Shaped products for covering streets, or for embankments, channels, arch and tunnel building, reservoirs for all liquids, etc.

V.—FIRING KILNS, OVENS, MUFFLES, Etc.

FUEL ECONOMY IN CHAMBER KILNS.—F. H. Haase and F. M. Meyer (*Tonind. Ztg.*, 41, 91, 556, 1917). A discussion bearing chiefly on the maintenance of the glow of heat as a means of saving fuel.

ROTARY TUBE KILNS.—C. Reinbold, D. Remare, A. B. Helbig and others (*Tonind. Ztg.*, 41, 271, 329, 355, 378, 384, 452, 529, 593, 1917). When the rotary tube kiln appeared in the field about the beginning of the century, great hopes were fixed on its introduction into the cement industry. The subject is discussed, and the author concludes that the high expectations entertained have only been to a small extent fulfilled, so far as German circumstances are concerned. Co-operation between cement technologists and machinery builders is suggested with a view to finding remedies for defects. Remare takes a different view of the rotary kiln. Helbig further discusses the question. At p. 384 Reinbold answers Helbig.

FIRE BOXES FROM CONCRETE.—S. K. (*Tonind. Ztg.*, 41, 314, 1917). From a lean cement mixture have been made pieces 3 cms. thick, which were

used for making a fire box and a cover with feed-hole closed by a plate of similar material. Cracks were formed but gave little or no trouble after cementing them.

ANNULAR KILN.—O. Thierbach (*Tonind. Ztg.*, 41, 523, 1917). The manner of charging fresh coal is open to improvement, cold air passing freely into the kiln. To prevent this, a special contrivance has been satisfactorily used. The shoot consists essentially of a kiln tube about 40 cms. long, which fits in the sand cup of the feed-hole. About the middle of the tube is fixed a crown, against which a closing lid can be applied. Above is the tube combined with a funnel, the bottom of which is provided with a sand cup at the neck of a heat-opening. On the closing lid is fastened a wire leading to a lever, a weight keeping the lid closed. The employment of the contrivance—which is figured—is extremely simple. The fuel is thrown into the neck of the heat-opening, and remains lying on the lid. After adjusting the bell with the peep-hole, which is closed by a mica plate, the lever is worked to lower the lid, letting the fuel fall into the kiln. Introduction of cold air is thus quite obviated. As the fire progresses the shoot is supported more and the feed-hole is covered in the usual way with a heat-bell. The peephole in the heat cover makes observation of the fire possible, the lid being always dropped by means of the lever in order to give a free view.

SEGER CONES WITH MIRROR TUBES.—(*Tonind. Ztg.*, 41, 587, 715, 1917). It is suggested that observations may be made quite independent of the fireman by using mirrors placed at the junctions of tubes running at right angles to each other. Thus a horizontal tube set in the direction of the cones may have its outer end connected with a vertical tube, and the upper end of the latter may be connected with another horizontal tube (as figured in the article).

SINTERING.—B. Kerning and others (*Tonind. Ztg.*, 41, 640, 683, 755, 778, 791, 831, 1917). A discussion of the use of the terms sintering and clinkering in connection with cement. At p. 683 it is taken up by another correspondent (H. H.) The third contribution (p. 755) is by H. Kühl. Kerning replies on p. 778. The contribution on p. 791 is by W. Büge. On p. 831 R. Rieke joins in the discussion.

GAS FIRING IN CERAMICS.—F. H. Haase (*Tonind. Ztg.*, 41, 674, 784, 825, 1917). A theoretical discussion founded mainly on an article by H. Klehe in *Tonind. Ztg.*, 1908, No. 51. R. Burghardt takes it up on p. 784.

ZIGZAG KILN FOR BURNING GROG.—P. Baier and others (*Tonind. Ztg.*, 41, 739, 809, 832, 862, 1917). Zigzag kilns are not suited for the purpose, as the necessary temperature cannot be reached, viz. Seger cone 12 to 14 (1,370° to 1,450° C.). The best kiln is the annular kiln with gas firing.

ANNULAR KILN.—R. Burghardt (*Tonind. Ztg.*, 41, 749, 1917). A short note on the advantage of having a two-part closed compartment, so that the air can be well heated.

TUNNEL KILN.—(*Tonind. Ztg.*, 41, 879, 1917). A general discussion.

COKE-OVEN MASONRY.—(*Tonind. Ztg.*, 41, 927, 1917). A general discussion.

SIMPLE PROCESS FOR DETERMINING HEAT VALUE OF COAL.—(*Ker. Rund.*, 25, 274, 1917). Reference is made to Berthier's process by heating coal with litharge, and to Muck's process of heating coal in an iron crucible. A definite relationship between the values so found, and the values found by using a calorimeter directly is discussed.

BAKING GRAPHITE CRUCIBLES.—E. Muller Company (*Pat. J.*, No. 1,502, 1917). Pat. No. 109,247, Aug. 29th, 1916. Graphite articles, such as crucibles, refractory bricks, etc., are baked in a reducing atmosphere in direct contact with the heating gases.

SHAFT KILN.—A. Steiger and W. W. Steiger (*Pat. J.*, No. 1,502, 1917). Pats. Nos. 109,264 and 109,266, Aug. 26th and 30th, 1916. The distinguishing features are a distributing cone which directs the larger lumps to the middle, and a discharging device consisting of a rotating plate. See also TRANS., 17, 250, 1918.

TILTING OPEN-HEARTH FURNACES.—A German firm (*Pat. J.*, No. 1,502, 1917). Pat. No. 109,419, May 7th, 1917. A preheating hearth is placed at the end of the furnace opposite the heating burner.

ELECTRODE FURNACES.—J. O. Boving (*Pat. J.*, No. 1,503, 1917). Pat. No. 109,465, Sept. 7th, 1916. An electrode is adjusted by a fluid-pressure power device controlled by valve gear operated electro-magnetically.

CRUCIBLE FURNACES.—Richmond Gas Stove and Meter Co. and H. Hartley (*Pat. J.*, No. 1,503, 1917). Pat. No. 109,586, April 16th, 1917. In a gas-heated furnace, the waste gases from the crucible chamber are passed in succession through a preheating chamber (for the metal or other substance to be melted) and an air-heating chamber traversed by the air pipe. The crucible chamber has a removable bottom.

ELECTRODE FURNACES; RESISTANCE FURNACES.—J. J. Denton (*Pat. J.*, No. 1,504, 1917). Pat. No. 109,639, Aug. 21st, 1916. A furnace having a resistance of material which is non-conducting when cold (as sand, clay, chalk, furnace waste, or mixtures of them), is started without external heating, by the use of an ionizing substance. A mixture of caustic alkali and sand may, for instance, be made into a cartridge and placed on the resistance between the electrodes, or may be sprinkled in a gully in the resistance. On wetting the alkali, it conducts and heats the resistance to conductivity. General or local increase of temperature may be produced during working by adding a reacting material such as lime.

COKE-OVENS AND FURNACES.—D. and E. A. Bagley (*Pat. J.*, 1,504, 1917). Pat. No. 109,752, April 26th, 1917. In a coke-oven or gas-heated furnace with vertical or horizontal heating flues, the gas conduit is made of fused silica, vitreous porcelain, or like ware, to prevent leakage of gas into the air flues.

CUPOLA FURNACES.—A. Poulson and W. C. A. Mate (*Pat. J.*, 1,507, 1917). Pat. No. 110,283, March 6th, 1917. The blast is led tangentially into an annular chamber surrounding the cupola, and delivered through a series of tangential tuyere holes, preferably curved, into the furnace.

ELECTRIC FURNACES.—V. Stobie (*Pat. J.*, No. 1,508, 1917). Pat. No. 110,409, Oct. 26th, 1916. An electrode on to which new sections are joined as it is consumed is surrounded by a closed chamber (of brickwork or cast-iron) extending from the furnace roof to a point where the electrode is too cool to burn. The chamber may be telescopic, one part being secured around the electrode.

MUFFLE FURNACES.—F. J. Grocott (*Pat. J.*, No. 1,508, 1917). Pat. No. 110,443, Dec. 7th, 1916. A gas-fired furnace for annealing, case-hardening, etc., is so constructed and arranged that by the opening and closing of certain passages, as for instance by dampers, the furnace may operate for the treatment of metals with an oxidizing flame, a non-oxidizing flame, or as a box muffle.

TUNNEL KILNS.—J. T. Price and W. J. Price (*Pat. J.*, No. 1,509, 1917). Pat. No. 110,531, Aug. 2nd, 1917. Air heated in channels in the furnace walls, and in a chamber above the furnace crown is delivered to a tunnel dryer for bricks, etc., by pipes.

TUNNEL KILNS.—C. Dressler (*Pat. J.*, No. 1,511, 1917). Pat. No. 110,918, Aug. 11th, 1916. In a tunnel kiln or oven having longitudinally arranged combustion flues as described in Specifications 18,114/10, 8,228/12, 8,505/13, and 18,221/13, the high temperature zone of the kiln is prolonged by introducing fuel and air into the combustion flues at different points along their length. The combustion points may be close together so that a substantially uniform high temperature is maintained over a length of the kiln, or they may be spaced so that the goods pass successively through zones of high and lower temperatures.

BLOWPIPE BURNERS IN FURNACES.—H. J. Yates, S. N. Brayshaw and E. R. Brayshaw (*Pat. J.*, No. 1,511, 1917). Pat. No. 110,960, Nov. 21st, 1916. In a metallurgical or other furnace the air and gas nozzles are arranged at right angles to one another with the gas nozzle arranged at right angles to the vertical branch of an L-shaped combustion chamber and with the air nozzle in alignment therewith, the horizontal branch of the combustion chamber being flared or having inclined sides so as to spread out the flames laterally as it enters the furnace. The air and gas pipes may be heated by carrying them through the flue and across the top of the furnace.

ELECTRODE FURNACES.—J. L. Dixon (*Pat. J.*, No. 1,512, 1918). Pats. No. 111,103 and 111,104, Oct. 15th, 1917. An arc furnace for steel is supplied with current by two-phase transformers having each of the two secondary windings divided into two equal sections, which are connected so that the vector diagram is a square. Sections alternately from the two secondaries form a closed series circuit but with the two sections of each secondary in reverse directions. Four upper electrodes are connected to the intermediate conductors. No connection is made to the hearth.

Ammeters or other devices in series with the electrodes can then indicate or bring about the requisite manual or automatic regulation of the electrodes, no voltmeters or the like being necessary.

INDUCTION FURNACES.—A. Turner (*Pat. J.*, No. 1,512, 1918). Pat. No. 111,120, Aug. 16th, 1916. For the production of iron and steel and of cyanogen compounds, three furnaces are used in conjunction, two reverberatory furnaces being in connection respectively with the top and bottom of a cupola furnace.

RESISTANCE FURNACES.—C. E. Hearson (*Pat. J.*, No. 1,513, 1918). Pat. No. 111,207, Feb. 1st, 1917. In a furnace comprising a tubular chamber surrounded by resistance wiring, the expanding part of a thermostat consists of a supporting or enclosing member of the chamber. A brass tube surrounding a silica tube, resistance wiring, and a layer of asbestos tape has end flanges attached to flat rings of uralite, or the like. The inclination of the furnace can be varied.

RESISTANCE FURNACES.—S. Steinberg and I. Gramolin (*Pat. J.*, No. 1,515, 1918). Pat. No. 111,679, June 27th, 1916. In a steel furnace, carbon resistance rods above the charge are supported at their ends by copper or graphite blocks on metal holders which are water-cooled and are pressed inwards by springs and screws. The furnace is of carbon or graphite, so that the resistances are not oxidized. Direct or single or polyphase alternating current may be employed.

DISTILLING ZINC., Etc. (ELECTRIC FURNACES).—C. H. Fulton and D. B. Jones (*Pat. J.*, No. 1,516, 1918). Pat. No. 111,835, Aug. 10th, 1917. Apparatus for distilling zinc from ores, etc. Comprises a condenser and a

furnace adapted to receive the briquettes or the like of mixed ore, etc., and a reducing agent, of such composition as to retain their original form when heated to a distilling temperature by passage of electric current through them.

ELECTRIC FURNACES.—E. F. Northrup and Ajax Metal Co. (*Pat. J.*, No. 1,516, 1918). Pat. No. 111,844, Nov. 14th, 1917. Induction heating is effected by the use of high frequency currents, as obtained, for instance, by condenser discharge. Frequencies of 12,400 and 25,600 have been found suitable. The frequency may be varied by placing the condensers in parallel or across different sections of the inducing coil, or by non-inductive line construction. No iron core is employed in connection with the inducing coil. A power factor approximating to unity can be attained.

SHAFT KILNS.—A. Steiger (*Pat. J.*, No. 1,516, 1918). Pat. No. 111,854, Nov. 27th, 1917. In a shaft kiln for burning lime, cement, etc., the pressure and quantity of air supplied to the kiln are varied by controlling the air compressor and adjusting the cross sectional area of the delivery passages.

GAS RETORTS.—H. P. Bostaph and Bostaph Engineering Co. (*Pat. J.*, No. 1,516, 1918). Pat. No. 111,871, Oct. 30th, 1916. A coal-gas retort comprises an upwardly tapering vertical shell and a central duct, the space between them being divided by radiating webs into narrow distillation chambers, the inner edges of which communicate by holes with the central duct through which the gases are withdrawn.

PULVERULENT FUEL FURNACES.—J. E. Muhlfeld and V. Z. Caracrista (*Pat. J.*, No. 1,518, 1918). Pat. No. 112,155, Sept. 13th, 1915. Several forms are described and illustrated.

RESISTANCE FURNACES.—Sir G. B. Filmer and J. J. Denton (*Pat. J.*, No. 1,518, 1918). Pat. No. 112,177, Jan. 23rd, 1917. A heating resistance of material non-conducting when cold, for instance magnesia, sand, or clay, wholly or partly surrounds one or more removable tubes or muffles, or supports plates in or on which may be placed cupels, etc., or a substance to be heated. The removable tube or the like may be of fused zirconia, or of ordinary crucible material. An initial path for the current is provided by adding to the non-conducting material a fusion mixture such as wet caustic soda. When hot enough to conduct, the removable tube can be employed as an independent heater, either in the furnace or apart therefrom.

GAS-FIRED FURNACES FOR POTTERY, Etc.—H. J. Yates, S. N. Brayshaw, and E. R. Brayshaw (*Pat. J.*, No. 1,519, 1918). Pat. No. 112,365, April 28th, 1917. The walls of a gas furnace primarily for firing pottery, but applicable also for other purposes, are built with a regenerative chamber wherein the waste gases of combustion heat burners placed in them, the gas and air supply pipes and fittings being placed outside the furnace. A sectional elevation is given.

LIQUID FUEL FURNACES.—A. J. Borener (*Pat. J.*, No. 1,520, 1918). Pat. No. 112, 421. Oct. 26th, 1917. The pipe supplying compressed air to the spray burner and combustion chamber of a rivet-heating or other metal-heating furnace is arranged and fitted so as to prevent explosions which occur owing to the entrance into the air pipe, when the furnace is not in use, of vapour from oil leakages.

LIQUID FUEL FURNACES.—R. Halkett (*Pat. J.*, No. 1,521, 1918). Pat. No. 112,700, March 24th, 1917. Relates to an oil-fired furnace front fitting consisting of a plate supporting concentrically a casing and a cylinder.

GAS MANUFACTURE.—N. T. Thaberg (*Pat. J.*, No. 1,520, 1918). Pat. No. 112,443, Dec. 20th, 1917. Relates to a process for producing gas from moist fuel such as peat.

RESISTANCE FURNACES.—L. W. Wild and E. P. Barfield (*Pat. J.*, No. 1,522, 1918). Pat. No. 112,731, June 26th, 1917. Relates to electric furnaces for hardening steel, etc.

LIQUID AND GASEOUS FUEL FURNACES.—I. Hall (*Pat. J.*, No. 1,522, 1918). Pat. No. 112,827, Jan. 31st, 1917. In a crucible or other furnace, liquid or gaseous fuel burners are arranged to discharge tangentially.

COKING.—D. Campbell and C. Goodyear (*Pat. J.*, No. 1,523, 1918). Pat. No. 112,967, Jan. 12th, 1917. The floor of a coke oven rests upon a permeable mass of finely-divided material and is formed with uniformly distributed apertures for withdrawal of the distillation gases, and with means for trapping and facilitating the removal of any dust or solid matter that may pass through the floor apertures.

ZINC RETORT FURNACES.—L. van Gulck (*Pat. J.*, No. 1,526, 1918. Pat. No. 113,393, June 23rd, 1917. A reversible gas-heated retort or muffle furnace, more especially applicable for the treatment of zinc. Comprises a number of compartments arranged in pairs on opposite sides of a central longitudinal wall reaching nearly to the roof, gas and air being supplied alternately to combustion chambers running longitudinally beneath each row of compartments, and regenerators for the air being arranged below. The flames from the combustion chamber in action rise between the retorts in the compartments on one side of the central wall and descend between these in the compartments on the other side to the regenerators on that side. Each pair of compartments is divided by the central wall into sections in which the muffles are arranged back to back.

CHARGING AND DISCHARGING RETORTS AND COKE OVENS.—J. Pieters (*Pat. J.*, No. 1,526, 1918). Pat. Nos. 113,435 and 113,436, Jan. 22nd, 1918. Relates to apparatus for charging continuous vertical retorts or coke ovens, comprising means for distributing the charge uniformly over the mouth of a single oven or over a battery of ovens, and for compressing the charge. Uniform descent is thus ensured, and a tight seal at the upper end of the ovens can be maintained by the charge alone. Also apparatus for discharging coke from vertical retorts.

SCREENS FOR FURNACES.—Richmond Gas Stove & Meter Co. and J. Thompson (*Pat. J.*, No. 1,527, 1918). Pat. No. 113,594, May 14th, 1917. Relates to a screen or guard to protect the operator from the heat and issuing gases. The lower part, which is inclined away from the furnace, is formed in two parts with a central gap or opening between them, through which articles may be passed into the furnace and inspected therein. A hinged or movable transparent portion is fitted across the gap.

COKE OVENS AND FURNACES.—Simon-Carves, Ltd., and J. H. Brown (*Pat. J.*, No. 1,527, 1918). Pat. No. 113,696, March 24th, 1917. In a coke oven or muffle furnace installation with heating-flues between the walls of adjacent ovens, the air and gas for combustion are heated in passages situated between flues for the outgoing products of combustion.

COKE OVENS.—A Belgian firm (*Pat. J.*, No. 1,528, 1918). Pat. No. 113,779, Nov. 9th, 1917. Ovens with horizontal coking chambers and vertical heating flues between them are provided with regenerators in their lower parts for generator gas and air, which are worked without reversal. Supplemental burners for coke-oven gas are located between the air and gas channels of the main burners.

COKE OVENS.—J. Pieters (*Pat. J.*, No. 1,528, 1918). Pat. No. 113,782, Jan. 22nd, 1918. In a continuously operated vertical oven for the distillation of coal or other materials, the coke is cooled before discharge by passing air or combustible or other gas through flues at the lower part of the oven.

TUNNEL KILNS.—J. H. Marlow and Minton, Hollins & Co. (*Pat. J.*, No. 1,528, 1918). Pat. No. 113,794, Dec. 4th, 1916. Gas-fired pottery and like kilns, through which the goods are conveyed on trucks, are constructed with two lateral combustion chambers, running along the base of the kiln, from which the flames pass directly to lateral conduits above them, thence through transverse flues in the arched roof to the conduits (alternately) on opposite sides. The conduits are constructed of curved slabs having on their convex faces cavities through which air is drawn and superheated. They may be formed with both sides independent of the wall of the kiln. The outer walls of the tunnel are built in sections to allow for expansion, the joints being covered by slabs having cavities or recesses for sand or the like. The trucks for the goods have their sides shaped to the contour of the channels, and their tops are perforated and formed with air cavities. From the firing chamber the trucks pass into a cooling chamber having a hollow arched roof with perforations to the interior.

ELECTRIC FURNACES.—Brown, Boveri & Co., and A. Gray (*Pat. J.*, No. 1,528, 1918). Pat. No. 113,827, March 6th, 1917. An electrode is adjusted in position by a reversible direct-current motor, supplied with current in either direction by a dynamo, the excitation current of which is controlled and reversed automatically, so that the power supplied to the motor is proportional to the variation of the furnace current from the normal. Several arrangements are described. In a polyphase furnace, each electrode may be adjusted independently, a common source of excitation current being employed; or a single motor may adjust all the electrodes, the regulator being connected to transformers in circuit with the electrodes. In a direct-current furnace the regulator may be shunted on a low resistance in the electrode circuit.

RESISTANCE FURNACES.—M. J. Insull (*Pat. J.*, No. 1,528, 1918). Pat. No. 113,839, March 8th, 1917. Resistance furnaces for reducing metallic oxides (as tungsten trioxide) to metals. A nickel lining extending only over a part of the length of the furnace protects both the silica or other refractory wall of the furnace, and a surrounding nichrome heater, from injurious low oxides of tungsten, etc. The lining may be a thin sheet retained by its own elasticity. Around the silica tube, except at its ends, is a packing of magnesia in a metal casing.

RADIATION PYROMETER.—A. Hilger, Ltd., and T. R. Merton (*Pat. J.*, No. 1,528, 1918). Pat. No. 113,865, March 31st, 1917. A radiation pyrometer comprises two radiation measures in the form of thermopiles, lenses in tubes for throwing on to the thermopiles radiations from the source of which the temperature is to be measured, and means for producing a difference between the radiations falling on the thermopiles, the difference between or the ratio of the E.M.F's produced indicating the temperature. The difference between the radiations may be caused by the provision of two filters (one red and the other green) or of only one filter, the intensity of the unfiltered beam in the latter case being compensated for by reducing its size. A telescope may be provided to enable the instrument to be adjusted so that identical images are produced on the thermopiles.

RETORTS.—J. West and W. Wild (*Pat. J.*, No. 1,529, 1918). Pat. No. 113,981, Dec. 9th, 1916. A plant for the destructive distillation of coal, etc. Comprises a number of horizontal or inclined retorts each horizontally narrow in end-on section and enlarging towards its outlet. The retorts are heated at the entrance so as to carbonize an outer skin around the charge, thus facilitating progression of the charge. The hot waste gases from the combustion chamber at the entrance of the retort are led round the middle zone of the retort, and the exit end of the retort is used to heat the air travelling to the combustion chamber.

GASEOUS FUEL FURNACES.—A. C. Ionides (*Pat. J.*, No. 1,530, 1918). Pat. No. 114,223, April 16th, 1917. A crucible-heating or other furnace of the kind described in Specification 108,701, utilizing a self-burning gas and

air mixture, is constructed with vertical combustion chambers supplied with gas and air at their lower ends and communicating with the upright tubular heating chamber by slits or orifices. The combustion chambers may be formed by semicylindrical grooves in the jointing-faces of the blocks or slabs forming the inner wall of the furnace, and the slits may be approximately radial or tangential, or the combustion chambers may be wholly in one of the jointing-faces, the inner surfaces of the slabs being cut away at one side to form (with projections) the slits or orifices. The gas and air nozzles deliver vertically or tangentially to the combustion chambers, and the combustion products may be vented downwards through an annular passage between the inner and outer walls, or partly also downwardly from the heating chamber itself.

ROTARY FURNACES AND KILNS.—Commercial Research Co. (*Pat. J.*, No. 1,530, 1918). Pat. No. 114,228, April 24th, 1917. In a cement furnace or kiln, flow and return channels for air or other cooling gas are arranged between the shell and the refractory lining, the air or gas being forced through them by a fan or other means. The refractory lining stops at a point short of the upper end of the kiln, and beyond this point there is an inner cylinder between which and the casing is a helical flue, the casing being provided at this part with an external heat-insulating covering. The raw material is introduced into the inner cylinder, and the clinker withdrawn at the lower end of the kiln adjacent to the firing-means.

ELECTRIC FURNACES.—J. R. Hoyle and P. Fawcett (*Pat. J.*, No. 1,531, 1918). Pat. No. 114,395, Oct. 29th, 1917. An electrode is protected just outside a furnace by a casing made wholly or partly of flexible refractory material, such as asbestos cloth with or without metal strands, or cloth woven from wire thickly covered with asbestos. Several forms of casing are described.

CRUCIBLE FURNACES.—J. Gaunt, D. Brookfield, and J. Tylor & Sons (*Pat. J.*, No. 1,533, 1918). Pat. No. 114,684, April 30th, 1917. The blast is preheated by passing it through circuitous conduits between the outer casing and the refractory lining, formed by ribs projected from the casing. It is delivered to a dished ash-pan, formed with a central indented portion and hinged to the casing. The grate is supported by projections resting on lugs, from which it may be disengaged by turning it on its axis. It has a central block to support the crucible.

ELECTRIC FURNACES.—Arendal Smelteverk (*Pat. J.*, No. 1,534, 1918). Pat. No. 114,841, April 5th, 1918. An electrode-holder comprises two bent arms embracing the electrode and crossing (a second time) so that, if their ends are forced apart, the electrode is clamped.

INDUCTION FURNACES.—C. B. Foley (*Pat. J.*, No. 1,534, 1918). Pat. No. 114,853, April 13th, 1916. A core limb is placed in a passage, situated relatively to the bottom of a crucible so that the intervening channel for molten material widens from the bottom upwards, the narrowest part of the channel being in the plane of the core. Two or more parallel core passages may be arranged so that the horizontal distance between them is greater than that between a passage and the wall of the crucible. Each core winding may then be connected to a reversing switch so that the currents around the passages may be in the same or opposite directions; in the former case there is little or no heating between the cores. The switches may be arranged so that one or more cores may be put out of action.

RETORT FURNACES.—Drakes, Ltd., and W. A. Drake (*Pat. J.*, No. 1,534, 1918). Pat. No. 114,859, July 30th, 1917. In regenerative retort settings with a producer and regenerators situated within the arch which supports a set of retorts, the secondary air flues are arranged so that some or all of them will end in common chambers, at the exit end of which the flow of air is controlled. The flues are also arranged so that part of the heated air may be used for primary combustion in the producer.

COKE OVENS.—H. B. Porteous and P. T. Allen (*Pat. J.*, No. 1,534, 1918). Pat. No. 114,936, June 9th, 1917. In horizontal ovens the heating flues in the walls between the coking-chambers are arranged so that the return flues are disposed between two horizontal combustion flues to which gas and air are supplied at one end. The air for combustion first travels the full length of the oven through flues at the top, then descends a flue at the end and again traverses the full length of the oven through flues below the sole and between the waste heat flues, and finally ascends at the ends of the combustion flues. The means for regulating the supplies of gas and air are disposed at one end of the oven.

TUNNEL FURNACES.—F. W. Harbord (*Pat. J.*, No. 1,535, 1918). Pat. No. 114,953, Aug. 9th, 1917. Relates to ore-roasting furnaces of the continuous tunnel type. They are provided with a series of hearths for carrying the ore capable of being moved to and fro longitudinally of the furnace. The furnace comprises two longitudinally disposed portions, one of which is muffled and externally heated.

COKING, Etc.—J. A. Yeadon and T. Whitaker (*Pat. J.*, No. 1,535, 1918). Pat. No. 114,971, Sept. 24th, 1917. Relates to the carbonization of coal, lignite, cannel, shale, peat, etc., by continuously passing the material, finely ground, through a uniformly heated vertical retort. The coke is removed continuously practically as soon as formed.

GAS PRODUCERS.—H. A. Greaves and H. Etchells (*Pat. J.*, No. 1,536, 1918). Pat. No. 114,983, Oct. 16th, 1917. A gas-generating appliance carried by and propelling vehicles, tractors, aircraft, and launches. Comprises a generator having a refractory lining and a water jacket around it, steam from which is blown under a rockable grate. The gas is led through a settling chamber provided with staggered baffles, and having, if desired, heat-radiating fins, to a water-sealed bell receiver, whence it may be exhausted to the engine.

ELECTRODE FURNACES.—J. G. Webb (*Pat. J.*, No. 1,535, 1918). Pat. No. 115,017, Sept. 25th, 1917. With the object of diminishing loss of heat and damage to the furnace, a crater is formed within a mass of scrap iron or other metal to be melted by an arc between electrodes arranged at an inclination steeper than the maximum slope of the side of the crater, so as to prevent the arc running up the charge. The electric pressure must not exceed a critical value at which, for the particular angle of the electrodes, the arc runs up them. Initially, separate arcs are struck between the electrodes and the flat surface of the charge, then the craters coalesce, and subsequently the electrodes are swung towards each other so that arcs play directly between them as well as on the charge. The final operations are conducted in the usual manner.

OIL OR GAS-FIRED FURNACES.—Burdons, Ltd., W. M. Burdon and M. M. Burdon (*Pat. J.*, No. 1,536, 1918). Pat. No. 115,214, Jan. 17th, 1918. In an oil or gas-fired furnace having means for delivering blasts of cooling air in front of the doorway when the door is opened, to protect the operator from issuing hot gases, a damper is arranged to be opened by the opening of the door, so as to reduce the pressure within the furnace, and valves are provided in the air-supply pipes, and operatively connected with the door-operating mechanism, so that air issues only when the door is opened.

CRUCIBLE FURNACES.—J. Gaunt, D. Brookfield, and Tylor & Sons (*Pat. J.*, No. 1,536, 1918). Pat. No. 115,222, April 30th, 1917. A furnace as described in Specification 114,684 is provided with means for preheating the charge, comprising an upward extension of the cover with a hopper or refractory lining having a depending internal extension formed as part of the lining of the cover and preferably curved so that the issuing gases become more intimately mixed with the charge in the hopper.

SHAFT KILNS.—J. P. Scheffers and M. A. van Roggen (*Pat. J.*, No. 1,536, 1918). Pat. No. 115,232, April 16th, 1918.

ELECTRODE FURNACES.—British Electric Transformer Co. and F. E. Berry (*Pat. J.*, No. 1,536, 1918). Pat. No. 115,247, Jan. 31st, 1917. Furnaces having three upper and three lower electrodes supplied with current by independent three-phase transformer windings. The lower electrodes are arranged in the side wall but nearer the bottom than the top, and a switch is provided so that the lower electrodes can be short-circuited at starting or at other times. The lower electrodes may be in contact with the charge or embedded in the lining.

ELECTRODE AND RESISTANCE FURNACES.—V. C. Faulkner (*Pat. J.*, No. 1,536, 1918). Pat. No. 115,248, Feb. 2nd, 1917. For melting and refining non-ferrous alloys and for other purposes.

CALCINING FURNACES OR KILNS FOR LIMESTONE, Etc.—E. J. W. Richards (*Pat.J.*, No. 1,537, 1918). Pat. No. 115,316, June 7th, 1917. One or more perforated flues or chambers, of triangular or equivalent shape in cross-section, are arranged longitudinally along the whole bed of the furnace or kiln, for the supply of air to the limestone or other material being calcined.

FURNACES AND CONVERTERS.—A. Rollason (*Pat. J.*, No. 1,537, 1918). Pat. No. 115,323, June 16th, 1917. A cylindrical body with acid and basic linings running the whole length, but each occupying only half the circumference, is mounted to rotate on rollers in a cradle, which may be tilted on trunnions transverse to the axis of the body.

EXTRACTING ZINC.—New Delaville Spelter Co., and E. H. Shortman (*Pat. J.*, No. 1,537, 1918). Pat. No. 115,409, July 19th, 1917. Special arrangement of retort and condenser.

ELECTRIC SUPPLY FOR FURNACES.—T. H. Watson & Co., H. A. Greaves, and H. Etchells (*Pat. J.*, No. 1,538, 1918). Pat. No. 115,570, Sept. 17th, 1917. Refers to electric furnaces in which the hearth by reason of its resistance acts as a heating device.

MULTIPLE-CHAMBER KILNS.—T. West (*Pat. J.*, No. 1,538, 1918). Pat. No. 115,696, May 17th, 1917. A continuous or series kiln consists of a number of circular or rectangular chambers, each with a hollow floor, heated by gases passing from one to the other, and operating alternately with up-draught and down-draught, or all with up-draught.

ELECTRODE FURNACES.—O. Sahlin (*Pat. J.*, No. 1,539, 1918). Pat. No. 115,719, June 13th, 1917. Refers to furnaces such that arcs can be formed either on or independently of the charge, all the electrodes entering through the side walls in pairs in vertical planes, the upper electrodes being inclined downwards and the lower ones horizontal.

RETORTS.—H. J. Toogood and Dempster & Sons (*Pat. J.*, No. 1,539, 1918). Pat. No. 115,738, July 16th, 1917. Refers to vertical retorts which taper in both directions.

RESISTANCE FURNACES.—H. A. Greaves and H. Etchells (*Pat. J.*, No. 1,539, 1918). Pat. No. 115,866, April 11th, 1917. Granular resistance material is contained in ducts looped around the furnace chamber and separated by material which, when hot, allows a certain amount of current leakage between the ducts. Suitable materials for the loose resistance are ground coke, retort carbon, kryptol, carborundum, siloxicon, silundum, or a mixture of minerals such as cryolite and chromite. The partitions between the ducts may be of chromite, magnesite, carborundum, or silundum.

FIRING EARTHENWARE.—W. P. Edwards and J. Edwards & Sons (*Pat. J.*, No. 1,541, 1918). Pat. No. 116,241, Feb. 13th, 1918. Relates to contrivances for setting the ware for firing. A metal crank for supporting earthenware during firing comprises a base and a top connected by three vertical bars on which slotted supporting rings can be fitted.

FUEL-TREATING COMPOSITION.—J. W. Edmonds (*Pat. J.*, No. 1,541, 1918). Pat. No. 116,252, April 24th, 1918. A composition for use in treating fuel consists of common salt (100 lb.), sal soda (63 lb.), whiting (27 lb.), gum acacia (19 oz.), oxalic acid (15 lb.), with or without zinc sulphate (2 lb. 2 oz.) or lampblack, or both. The quantities indicated are mentioned as suitable, the lampblack added being sufficient for colouring. After mixing in specified manner, hot water is added, and the composition is sprinkled over the coal or other fuel.

TUNNEL FURNACES.—W. E. Watkins and Thermal Plating Process Co. (*Pat. J.*, No. 1,541, 1918). Pat. Nos. 116,294 and 116,295, June 11th, 1917. Relates to furnaces used in connection with a plating plant as described in Specification 107,201.

RETORTS.—H. R. L. Walker and W. R. Bates (*Pat. J.*, No. 1,542, 1918). Pat. No. 116,458, Nov. 17th, 1917. An annular vertical retort for destructive distillation, carbonizing, and roasting, heated externally and by means of an axial flue, is provided with an annular plunger adapted to compress the charge and assist its travel through, and discharge from, the retort. At the base of the retort a transverse knife edge is provided to facilitate discharge.

FIRING BRICKS.—Lambert Process Co. (*Pat. J.*, No. 1,543, 1918). Pat. No. 116,745, June 15th, 1917. The kiln or clamp of bricks is fired to produce a zone of incandescence in the neighbourhood of the combustion apparatus; the firing is then discontinued and the incandescent zone is caused to traverse the remainder of the clamp, preferably by means of a steam and air blast. The firing is conducted at such a rate that the draught is choked and a blanket of steam is formed in advance of the incandescent zone.

The clamp is fired by liquid fuel burners each having a central oil nozzle controlled by a needle valve, and a surrounding steam passage.

GAS MANUFACTURE.—H. J. Toogood and R. Dempster & Sons (*Pat. J.*, No. 1,543, 1918). Pat. No. 116,831, Oct. 27th, 1917. In vertical retorts the yield of gas is improved by injecting superheated steam and water gas, or carbon dioxide or producer gas into the lower part of the retort.

ELECTRODE FURNACES.—A Christiania Firm (*Pat. J.*, No. 1,543, 1918). Pat. No. 116,853, Jan. 9th, 1918. Carbon electrodes are made in continuous lengths by feeding a carbonaceous mixture into a hopper or mould leading into the furnace in which they are used, current passing through the raw material to bake it.

GASEOUS FUEL FURNACES FOR POTTERY, Etc.—W. Bennett (*Pat. J.*, No. 1,545, 1918). Pat. No. 117,147, July 16th, 1917. In a muffle kiln for firing pottery, etc., a combustion chamber is arranged longitudinally beneath the floor of the kiln about midway of its breadth, and is supplied with gas and air through passages extending from one side, the gas being admitted to the passages from a side main. The supplies of gas and air are controlled by suitable valves. The flames and products of combustion pass right and left below the muffle, then up the sides to the top.

TUNNEL KILNS.—G. H. Benjamin (*Pat. J.*, No. 1,547, 1918). Pat. No. 117,383, Nov. 12th, 1917. A continuous tunnel kiln for use in the manufacture of tiles, pottery, and the like. Consists of a main chamber or tunnel heated by closed combustion chambers arranged in line along its sides in

which gas is burnt, and by the circulation through the main chamber, and through the goods, of hot air which, after exhaustion from the goods chamber, may be in part used for combustion. The arrangements are illustrated by figures.

GAS-MIXING DEVICE.—Surface Combustion Co. and W. B. Eddison (*Pat. J.*, No. 1,548, 1918). Pat. No. 117,612, June 19th, 1918. In a gas-mixing device in which one gas draws a second gas into a Venturian mixing tube, the part of minimum cross-section is made of a length several times greater than its diameter so that the pressure of the gaseous mixture at the part where it enters the conical discharge part of the mixing-tube is substantially the same at any point on a transverse section. A mixing device for the burner of a surface combustion furnace is illustrated.

CRUCIBLE FURNACES.—C. F. Price (*Pat. J.*, No. 1,550, 1918). Pat. No. 118,000, Sept. 19th, 1917. A portable type with outer metal casing.

ELECTRIC FURNACES.—T. H. Watson & Co. and W. Travis (*Pat. J.*, No. 1,550, 1918). Pat. No. 118,023, Nov. 8th, 1917. Relates to devices for preventing leakage from a hole in the roof or wall through which an electrode passes.

GAS FURNACE BURNERS.—H. J. Yates, S. N. Brayshaw, and E. R. Brayshaw (*Pat. J.*, No. 1,552, 1918). Pat. No. 118,239, Oct. 16th, 1917. A furnace blowpipe burner comprises a tubular casing provided with co-axial air and gas nozzles. The end of the casing to which the air nozzle is attached may be open or closed by a hinged flap. The arrangement is figured.

GAS BURNERS.—A. C. Ionides (*Pat. J.*, No. 1,552, 1918). Pat. No. 118,313, Aug. 18th, 1917. In a system of supplying gas and air or their equivalent through suitable main conduits to any number of combustion apparatus, one of the fluids passes through a governor to limit its pressure, the other fluid is supplied at a greater pressure by a blower or other continuous-pressure creating device, the gas and air being further controlled by a pressure balancing device of the type set out in Specification 110,568 and comprising statically balanced or double-beat valves which are operated by a bell, diaphragm or other sensitive movable partition, subjected on opposite sides to air and gas pressure, to maintain a definite relationship between their pressures. Specifications 17,670/15 and 102,983 are also referred to.

ELECTRODE FURNACES.—Booth-Hall Co. (*Pat. J.*, No. 1,552, 1918). Pat. No. 118,357, Sept. 27th, 1917. One or more hearth electrodes, situated directly beneath the main electrodes, are replaced at starting by an auxiliary upper electrode, until the hearth has been heated to conductivity. Alternating current is preferred.

FIRING CERAMIC WARE.—Dressler Tunnel Ovens, Ltd., and H. J. Rushton (*Pat. J.*, No. 1,553, 1918). Pat. No. 118,429, July 25th, 1917. Relates to open-sided supports (of fireclay or metal) for saucers, plates, tiles, and other ceramic ware during glost-firing. The supports consist of a base and end walls, the base having two very short legs at one end and a similar central leg at the other end. The ware is supported by triangular saddles, and by pins mounted in bars fitting into slots in the ends of the supports. For self-supporting ware the saddles and pins are dispensed with. Specifications 18,114/10, 8,228/12, 8,505/13, 18,821/13, and 110,918 are referred to.

ELECTRIC FURNACES.—Ajax Metal Co. (*Pat. J.*, No. 1,557, 1918). Pat. No. 119,220, March 19th, 1918. Induction heating is effected by the use of high-frequency currents, obtained by condenser discharge or impressed by a high-frequency generator on an approximately tuned circuit containing the inducing coil. Frequencies of 12,600 and 25,400 have been found suitable. The power factor may be unity. No iron core is required in the heater. The

invention is applicable to the heating of metal billets or blooms to be worked, of thin metal shells, and of liquid or pasty substances. Solid bodies may be heated locally.

ELECTRODE FURNACES.—A. D. Keene (*Pat. J.*, No. 1,557, 1918). Pat. No. 119,228, Aug. 30th, 1918. In a furnace working with several arcs in series, one is controlled in accordance with current variations and is provided with a shunt connection, and another arc is controlled in accordance with pressure variations. Means are provided for automatically varying the working of the regulators to correspond with manual regulation of the supply pressure.

RESISTANCE FURNACES.—T. F. Bailey and F. T. Cope (*Pat. J.*, No. 1,557, 1918). Pat. No. 119,234, Sept. 4th, 1918. In a metal-melting furnace, resistance material such as granular coke, graphite, or carbon is contained in one or more troughs placed near the furnace wall and between the hearth and a roof serving as a heat reflector.

SHAFT FURNACE OR KILN.—C. Candlot (*Pat. J.*, No. 1,557, 1918). Pat. No. 119,235, Sept. 5th, 1918. An apparatus for discharging material at the base of a shaft furnace or kiln. Comprises cones mounted to rotate or oscillate on horizontal axes. The surfaces of the cones may be studded or ribbed, and they may be perforated for the supply of air. The material falls on a plate beneath, and is gradually swept off by the movement of the cones.

RESISTANCE FURNACES.—J. E. P. Kievits and Kynoch, Ltd. (*Pat. J.*, No. 1,557, 1918). Pat. No. 119,302, Oct. 13th, 1917. A wire resistance helix is wrapped in paper or the like before being embedded in refractory cement. The paper is afterwards burnt off, air being blown through the helix to complete the combustion and remove residue, so that the inner surface of the helix is left bare. The helix may surround a silica muffle or be applied to surfaces of other forms.

TUNNEL FURNACES.—E. E. Brand (*Pat. J.*, No. 1,558, 1918). Pat. No. 119,366, Jan. 2nd, 1918. The cooling portion or chamber of a tunnel furnace is formed with apertures in its roof or walls throughout its entire length for the admission of air, which is directed through such apertures at right angles to the stream of air for combustion passing through the furnace from the delivery end.

GAS FURNACES.—H. J. Yates, S. N. Brayshaw and E. R. Brayshaw (*Pat. J.*, No. 1,559, 1918). Pat. No. 119,553, Oct. 16th, 1917. The flames from a number of burners pass along a number of parallel passages beneath the furnace floor and rise through vertical passages into the furnace chamber. The products of combustion escape through openings to a chamber traversed by the air-supply pipes, and pass thence to the chimney flue. The burners are constructed and arranged as described in Specification 118,239.

ZINC FURNACE TEMPERATURES, I.—E. M. Johnson (*Met. Chem. Eng.*, 17, 300, 1917). Data on different kinds of ores and furnaces. The following temperature data were obtained by the author on a natural gas furnace with common retorts. They indicate the temperature in the open retort as indicated by Norton cones, which were placed at the back end of the retort, in the middle row, near the middle part of the furnace, the time being recorded when the top of the cone bent over to the clay. The cones certainly act as a warning with respect to getting "butchers," as in some cases it was found safe to get No. 7 cone down, with other ores No. 8, and in exceptional cases start No. 9. Table I represents the average of the daily records, and the author thinks that they are not very far from the temperatures existing in the open retort during the distillation period.

TABLE I. Cone Records for Natural Gas Furnace, Common Retorts.

Furnace Number	Month	Time of Attaining Temperature of						
		Cone 03 1,090° C	Cone 01 1,130°C	Cone 2 1,170°C	Cone 4 1,210°C	Cone 6 1,250°C	Cone 7 1,270°C	Cone 8 1,290°C
Part 1st. Charge—½ Leadville Calamine + ½ Western Sulphide.								
1	August ...	5.00	7.00	9.00	11.00	1.00	2.30	—
1	September ..	4.30	6.30	8.30	11.00	12.40	2.00	—
3	August ..	6.00	8.00	10.00	12.00	—	—	—
3	September ..	6.20	8.30	10.30	12.30	1.00	—	—
2	June ..	5.25	7.15	9.25	11.40	12.25	2.00	—
2	July ..	6.30	8.30	10.00	11.30	—	—	—
4	June ..	5.15	7.20	9.30	11.40	1.35	2.40	—
4	July ..	7.20	9.30	10.30	12.00	1.30	3.00	—
5	July ..	6.00	8.00	10.30	12.00	—	—	—
5	August ..	5.00	7.30	9.20	11.00	—	—	—
6	June ..	4.30	6.20	9.15	10.15	12.20	—	—
6	July ..	5.30	7.40	10.00	11.40	—	—	—
6	September ..	5.40	8.30	10.40	12.50	—	—	—
	Average time ..	5.40	7.40	9.45	11.35	1.20	2.25	—
Part. 2nd. Charge—⅔ Leadville Calamine + ⅓ Joplin.								
2	October ..	4.00	6.00	8.00	10.00	12.00	—	—
4	October ..	4.30	6.40	9.00	11.00	1.00	2.30	—
5	October ..	4.00	7.00	9.30	11.30	12.10	2.10	—
7	October ..	3.00	4.40	6.50	9.10	11.40	1.15	—
	Average time ..	3.50	6.05	8.20	10.25	12.15	2.00	—
Part 3rd. Charge—⅓ Leadville Calamine + ⅔ Joplin.								
7	August ..	1.00	2.20	4.10	6.20	8.30	10.30	12.20
7	September ..	2.00	3.40	5.50	8.00	10.00	12.00	—
9	August ..	1.00	2.40	4.40	7.00	9.00	10.40	12.30
9	September ..	1.00	2.30	4.30	6.30	8.30	10.30	12.20
8	June ..	1.20	3.15	5.30	10.30	12.15	2.30	—
	Average time ..	1.24	3.10	5.10	7.55	9.55	11.15	12.20
Part 4th. Charge—All Joplin.								
8	July ..	1.25	3.00	4.30	7.10	8.30	12.30	—
9	October ..	1.00	3.00	5.30	7.30	9.50	10.40	2.15
10	June ..	1.30	3.20	6.15	9.20	10.25	1.30	2.20
10	July ..	1.20	3.00	5.30	9.00	10.30	1.10	—
	Average time Part 3 and 4 ..	1.20	3.05	5.25	8.15	10.09	12.25	2.17

Analysis of Charge:	Zn	Fe	Mn	SiO_2	Pb
Leadville Calamine	30	10	3	12	—
Western Sulphide	50	17	—	2	2·4
Joplin	54·6	4·2	—	6·1	0·76

The temperatures in Table II were obtained with a regenerative furnace using hydraulic retorts. As before they indicate the temperature in the open retort as indicated by Norton cones, which were placed at the back of the retort in the bottom row about the middle of the furnace, the time being noted when the cone had bent over to touch the clay.

TABLE II. Cone Records for Regenerative Furnace, Hydraulic Retorts.

	Time when Temperature was attained of							
	Cone 03 1,090°C	Cone 01 1,130°C	Cone 1,170°C	Cone 4 1,210°C	Cone 6 1,250°C	Cone 7 1,270°C	Cone 8 1,290°C	Cone 9 1,310°C
Part 1st. Charge of Western Ore; Zn=53%, Fe=11%								
	1.07	3.00	5.50	8.15	9.40	11.30	2.30	—
	1 08	2.40	4.10	7.15	9.45	12.20	3.00	—
Average time	1.08	2.50	5.00	7.45	9.45	11 55	2.45	—
Part 2nd. Charge of Roasted Joplin Ore; Zn=67%								
	12.15	1.45	3.40	5.35	7.45	10.20	12.50	—
	1.00	1.50	3.45	5.50	8.00	10.35	1.40	3.20
Average time	12.40	1.50	3.45	5.40	7.55	10.30	1.15	3.20
Part 3rd. Charge of Silicate Ore, Low in Pb and Fe.								
Average time	1.10	2.30	4.15	5.50	7.25	8.40	10.30	12 20

All times represent the average reading for two months.

From the comparison of Tables I and II it will be observed that there is considerable difference between them with respect to the Western ores, while upon the Joplin ore they agree more closely. This is mainly due to the fact that some metallurgists when treating Western ores bring the furnace along somewhat faster and work it off closer, while others bring the furnace up slowly, holding it a little greener in the morning, and thereby obtaining more metal at the third draw. If the recovery be the same in both cases, the latter method is to be preferred, as it is easier on the retorts, the men, and the furnace.

The following is a log of furnace temperatures taken between the retorts in the laboratory of a *coal-fired furnace* of the *Hegeler type*, with no regenerators; $1\frac{1}{4}$ inch slack coal was used, and the furnace operated on Joplin ore. Charging of the furnace was commenced at 5 a.m. and finished at 11 a.m. The draught in the furnace was from 2 to $2\frac{3}{4}$ inches; in the producer it varied from $\frac{1}{2}$ inch just after coaling to 4 inches just before recoaling.

TABLE III. Pyrometer Readings in Degrees C. in Hegeler Furnace.

4th Sec., 3rd Row		14th Sec., 3rd Row		19th Sec., 3rd Row		
Time	Temp.	Time	Temp.	Time	Temp.	Remarks
A.M.		A.M.		A.M.		
10.55	1060	10 58	900	11.00	815	
11.28	1070	11.32	920	11.35	860	Clinkered. Air pressure off 8 min.
11.55	1085	11.58	970	12.10	890	
P.M.		P.M.		P.M.		
1.03	1130	1.15	1085	1.18	1015	Clinkered. Air pressure off 7 min.
1 52	1140	1.56	1100	2.00	1040	Coaled up ,, ,, ,, 4 ,,
2.46	1155	2.55	1125	2.58	1075	Clinkered ,, ,, ,, 7 ,,
3.42	1165	3.47	1150	3.51	1090	Coaled up ,, ,, ,, 5 ,,
4.58	1165	4.50	1160	5.09	1115	Clinkered ,, ,, ,, 8 ,,
5.55	1210	5.59	1180	6.04	1110	Coaled up ,, ,, ,, 3 ,,
6.55	1220	7.01	1210	7.06	1120	Clinkered ,, ,, ,, 9 ,,
				7.09	1090	
				7.15	1080	
7.58	1200	8.05	1220			Coaling up. Air pressure off 5 min.
8.53	1230	8.59	1200	9.03	1140	
9.22	1230	9.26	1215	9.30	1165	Clinkering. ,, ,, ,, 15 ,,
				9.31	1155	During this clinkering and coaling up,
				9.32	1130	the temp. dropped 60 in the blue
				9.33	1125	powder
				9.35	1110	
				9.42	1105	
				9.48	1140	
10.21	1240	10.26	1220	10.30	1165	
11.11	1265	11.16	1230	11.18	1190	Clinkering. Air pressure off 9 min.
				11.19	1170	Temp. in blue powder dropped 55°
				11.20	1155	
				11.23	1140	
				11.25	1140	
				11.27	1135	
		A.M.		A.M.		
12.19	1265	12.25	1230	12.27	1190	
12.59	1275					Clinkered. Air pressure off 9 min.
1.00	1270					Temp. in the fronts dropped 20°
1.01	1265					
1.03	1255					
1.04	1250	1.10	1230	1.14	1195	Coaling up. Air pressure off 5 min.
2.03	1275	2.45	1250			
		2.46	1250			Clinkering. Air pressure off 10 min.
		2.48	1245			
		2.50	1240			Middles dropped 20°
		2.53	1235			
		2.55	1230	3.00	1225	Coaling up. Air pressure off 3 min.
3.50	1270	3.59	1255	4.01	1215	
3.52	1255	4.50	1255	4.55	1195	
4 40	1275	5.48	1250	5.59	1240	Clinkering. Air pressure off 8 min.
Lowest	1,060		900		815	
Highest	1,275		1,255		1,225	Total time pressure off : 1 hour

In the following table are listed pyrometer temperatures in degrees C. in the laboratory of the furnace on both sides of the block :—

TABLE IV. Pyrometer Readings in Degrees C. in Coal Field Furnace, Regenerating Type.

	Time	Row No 1	Row No 2	Row No 3	Average
Section 2 ..	3.50 p.m.	1200	1220	1185	1201
,, 8 ..	3.50 ,,	1220	1230	1175	1208
,, 18 ..	3.50 ,,	1220	1230	1170	1207
Average ..	.. .. ..	1213	1227	1177	1205
Opposite Side—					
Section 2 ..	4.10 p.m.	1230	1235	1120	1195
,, 8 ..	4.10 ,,	1223	1250	1170	1213
,, 18 ..	4.10 ,,	1230	1230	1165	1208
Average		1227	1238	1152	1205
General Average		1220	1232	1165	1205

Conclusions.—There is too much variation in the volume of gas just before and after coaling up when using 1¼ inch screenings in a Hegeler producer for a non-regenerating type of furnace, due to the rapid combustion of such fine coal, which necessitates more frequent coaling up and consequent slight cooling of furnace. The fine coal with no steam blown into the producer forms large lumps of clinker, thus prolonging the clinkering time. By coaling up once an hour there was sufficient gas of very good quality, and the furnace picked up very well during the first stage of the operation (see Table III or V). But it was very difficult in the latter part of the process to force the backs (*i.e.*, 10th to 15th sections) without retarding and even cooling off the fronts. Further trouble was caused by the increased charging time due to the great amount of producer ash carried into the furnace laboratory, thereby forming an unusual amount of glaze in the furnace bottoms and upon the back lining and retorts. Under these conditions there is hardly any question but that the four-row furnace would at least give the the best recovery.

TABLE V. Recapitulation and Deductions from Tables I to IV ; Joplin Ore.

Reference	Location	Time when Temperature was attained of: Cone 03 1,090°C.	Cone 01 1,130°C.	Cone 2 1,170°C.	Cone 4 1,210°C.	Cone 6 1,250°C.	Cone 7 1,270°C.	Cone 8 1,290°C.	Cone 9 1,310°C.	Charging: Start A.M.	End A.M.
Table I, part 4	Open retort	1.20	2.57	5.10	7.55	9.43	12.00	1.10	—	4	9
,, II ,, 2	,, ,,	12.40	1.50	3.45	5.40	7.55	10.30	1.15	3.20	5	11
,, III col. 1	Laboratory*	11.55	1.03	5.00	8.00	10.20	12.20	5.00	—	5	10
,, IV ..	,, †	11.00	12.00	2.00	4.00	6.00	8.00	10.00	12.00	5	10

* The approximate time noted on this line was taken from the first column of Table III, and therefore corresponds to the 4th section only.
† Interpolated from the temperature at 4 o'clock which was 1,205°C. according to Table IV.

Table V indicates temperatures in the laboratory at a later time than the same temperature in the retort, though the heating atmosphere must attain

a certain heat before the heated body. But these comparisons of temperature are made on furnaces of different type, and merely confirm the actual facts that the furnace in question did not pick up in heat fast enough, and the blue powder could not be worked close enough, so the recovery was unsatisfactory.

Analysis of clinker, glaze, and slag gave:—

	SiO_2	FeO	CaO	Al_2O_3
Producer clinker ..	45.5	15.9	11.5	24.3
Retort glaze	61.6	13.7	4.7	20.3
Furnace bottom slag ..	53.9	9.5	5.4	27·1

ZINC FURNACE TEMPERATURES, II.—E. M. Johnson (*Met. Chem. Eng.*, 18, 14, 1918). The article is continued with a series of curves plotted from temperatures taken on the furnaces in the chequerwork during periods of reversing (the first reading being taken just before reversing). The curves show the fluctuations of temperature at points where the gas and air respectively enter the laboratory and the chequerwork, and where the combustion gases leave the laboratory of the furnace and the chequerwork of the furnace.

By means of the curves comparisons may be made between the temperatures at particular points at different times, between the long and short valve or between east side and west side, or between inside and outside chequers, etc., from which conclusions may be drawn relative to the construction of the chequerwork walls, or the height of the chequer, or the periods of reversing.

Temperatures were also taken of gases in the four channels between the valve boxes and the furnace, showing a comparison of results during a period of reversals of the gas or air entering on the east side and leaving on the west side. Thus the tabulated stack temperatures on the short valve (the pyrometer being enclosed in an iron pipe) during three successive reversal periods ranged on the east side from 358° to 415° C., and on the west side from 370° to 415° C., with general averages of 375° and 390° C. respectively. Similarly on the long valve (with pyrometer naked) the range on the east side was from 390° to 440° C., and on the west side from 410° to 475° C., with general averages of 396° and 417° C. respectively. A third table gives stack temperatures on the short valve taken in channels between the outside end walls and the furnace and damper boxes, showing a range from 130° to 480° C. (only 6 of the 24 readings below 320° C.) on the west side, and from 160° to 465° C. (only 5 of the 24 readings below 300° C.) on the east side, with general averages of 339° and 350° C. respectively.

INDUCTION FURNACES.—O. C. Bockman (*Pat. J.*, No. 1,561, 1918). Pat. No. 120,030, May 17th, 1918. A regulable magnetic path is arranged in shunt to the ordinary path, to permit control of the working of the furnace without regulating the current or circuit connections.

MULTIPLE CHAMBER KILNS.—E. Glossop and J. Sherlock (*Pat. J.*, No. 1,561, 1918). Pat. No. 120,052, Oct. 23rd, 1917. A continuous kiln is provided with a hot-air flue in the dividing wall between the lines of chambers, and outlet flues leading to main flues, in the partition walls between the chambers. Additional outlet flues opening from passages in the walls lead to the main flues. Ports in the partition walls allow the gases from a burning chamber to pass to adjacent chambers.

PULVERULENT FUEL FURNACES.—F. E. Whitham (*Pat. J.*, No. 1,563, 1918). Pat. No. 120,274, Nov. 9th, 1917. Powdered fuel and air are delivered to a combustion chamber opening into a flue containing a series of pockets for the collection of the incombustible portions of the fuel. The flue is preferably helical, though it may be straight.

AUTOMATIC COAL-STREWERS FOR ANNULAR KILNS.—P. Thor (*Deut. Töpf.-Zieg.-Ztg.*, 48, 400, 1917). The necessary conditions for the successful employment of such apparatus are discussed. The author finally concludes that the introduction of automatic coal-strewers for annular kilns gives rise to the following advantages: 1. Suppression of coke formation in the bottom flues, because by the regular charging of small quantities of coal these cannot be aggregated. 2. More uniform burning, because an automatic apparatus, which is correctly adjusted, works more uniformly than manual labour. 3. Great economy of coal, because the fuel thrown in is completely burned and thereby much more heat is developed than with incomplete combustion. 4. Likewise economy of coal in consequence of the abolition of the inflow of cold air through opening the heat cover in putting coal on. A less expense in firemen's wages is, on the other hand, not to be expected.

VI.—GLAZES AND GLAZING. ENAMELS.

LEAD ORE FOR FINE CERAMIC GLAZES.—H. Marquardt (*Ker. Rund.*, 25, 205, 1917). A brief record of trials, mostly unsuccessful. It can only be recommended to let the lead sulphide melt, and to use it for glazes in the same way as lead oxide hitherto.

CLOUDED ENAMELS AND GLAZES.—H. Kretzer, Swiss Pat. 73,471, May 1st, 1917. Silicon compounds of acid character are added to the enamel mixture (after melting and during grinding) to enable the product to give cloudy effects.

OPAQUE ENAMELS.—H. Kretzer and A. Cappel, U.S. Pat. 1,239,112, Sept. 4th, 1917. The opacifying agent, *e.g.*, a compound of zirconium, titanium, silicon, aluminium, zinc, or alkaline earth metals, is added to the other materials of the enamel after at least partial wet grinding, along with substances which precipitate colloids (ammonium chloride, magnesium sulphate or chloride, or sodium sulphate), or precipitating colloids. Addition of the opacifier after partial grinding of the enamel produces a better opacifying effect.

GLAZE FAULTS.—E. Brüch (*Tonind. Ztg.*, 41, 40, 1917). A brief account of trouble arising from the introduction of too much potash, which being too damp had been dried before weighing out.

GLAZE FAULTS.—E. Börner (*Tonind. Ztg.*, 41, 87, 277, 1917). Reference is made to E. Brück's article (above). An experience is mentioned in which a glaze was prepared which was perfectly clear and bright. When put on ware it came out brilliant, only all the edges of the upright burned pieces were transparent reddish, and the glaze was apparently too easily fusible. However, when the melting of the glaze was carried a little further the fault vanished, and ever since a well-melted glaze and covered edges have been obtained. The remarks on p. 277 are by D. R.

GLAZING MACHINES FOR PLATES.—C. Nesemann (*Tonind. Ztg.*, 41, 306, 1907). A short note on the use of the machine.

MECHANICALLY GLAZED PLATES.—E. Müller (*Tonind. Ztg.*, 41, 369, 1917). A further reference to the use of the machine mentioned in C. Nesemann's note.

STONEWARE GLAZES.—W. Büge (*Tonind. Ztg.*, 41, 589, 1917). A brief discussion. For salt glazes the composition ranges between $Na_2O.0{\cdot}6Al_2O_3.5{\cdot}5SiO_2$ and $Na_2O.1Al_2O_3.2SiO_2$. The earthy glazes range between $0{\cdot}4CaO.0{\cdot}6Na_2O.0{\cdot}3Al_2O_3.4SiO_2$ and $0{\cdot}8CaO.0{\cdot}2Na_2O.0{\cdot}6Al_2O_3.6SiO_2$.

USE OF ZINC SULPHIDE FOR WHITE AND LUMINOUS ENAMELS.—J. Schæfer (*Ker. Rund.*, 25, 75, 1917). German patent 289,317 is mentioned, and references are made to periodical and other literature. The results of

various trials with enamels are given (containing about 5 per cent. cryolite), using 5 per cent. of zinc sulphide, at a temperature of 800° C. It was found that the zinc sulphide possesses good covering power, and was not decomposed into zinc oxide. Trials in which the latter was used indicated little or no covering power. The covering power of the sulphide was as great as that of tin oxide, but the white colour and lustre were not so good. At 1,000° C. the covering power of the zinc sulphide enamel had almost gone. This weakening of covering power, and the yellowish coloration of the enamel, are explained by double decomposition between the zinc sulphide and the oxides of the ground enamel at 1,000°, as was demonstrated by using the same mixture for both coats, when a good covering white was obtained at 1,000° C., the covering power being lost only at the edges where the coating was thin. Further trials showed that zinc sulphide was not decomposed in glazes not readily fusible, but lustre is slight. The foregoing trials were all made on sheet iron, but zinc sulphide has also proved very suitable for cast-iron enamels. Special zinc sulphide is now produced, which gives bright enamels. It cannot be used for coloured enamels, owing to decomposition and resulting decoloration, so the only other metals which can be present are lead, antimony, and arsenic.

POTTERY.—Elektro-Osmose Akt.-Ges (*Pat. J.*, No. 1,528, 1918). Pat. No. 113,777, Sept. 27th, 1917. Ceramic ware is provided with a lustrous coating by applying the coating material in the colloidal state in the sol condition and firing the ware at a temperature below the fusing point of the coating. The coating material may consist of clays, kaolin, silicates, zirconia, carborundum, etc. Finely divided materials such as clay or kaolin are formed into a thin magma and a small proportion of a suitable electrolyte, *e.g.*, water-glass, added. By allowing the suspension to stand, the coarser particles are separated, leaving a finer suspension, the degree of fineness corresponding to the lustre desired. Non-plastic substances may be brought into the sol condition by mechanical and chemical treatment, *e.g.*, as described in Specification 14,235/12; also the substance may be purified as described in Specification 2,379/11.

ENAMELLING FURNACES.—P. Dupont (*Pat. J.*, No. 1,533, 1918). Pat. No. 114,618, Feb. 14th, 1918. Relates to the enamelling of metal articles by the powdering process and consists in powdering the article in a single operation under an increasing temperature; and comprises also a construction of gas furnace for carrying out the process, such furnace being applicable to the heating of metal articles in general, steam-generators, etc. The invention is described in connection with the enamelling of the interior of cast-iron baths.

ENAMELLED METAL TILES, PLATES, Etc.—Stocal Enamelled Tile & Iron Co. and A. A. Mead (*Pat. J.*, No. 1,533, 1918). Pat. No. 114,671, April 16th, 1917. Relates to enamelled metal tiles or plates for covering walls, ceilings, etc., having bent or pressed edges to key with the surface, and consists in forming the tiles, etc., with a camber prior to enamelling to allow for sagging during firing. The edges may also be serrated, slotted, or perforated so as to yield during firing and obviate ridging.

LEAD ORE FOR FINE CERAMIC GLAZES.—H. Hirsch (*Ker. Rund.*, 25, 189, 1917). An account of trials made to ascertain how far native lead sulphide might be made available. The author concludes that it forms no useful substitute for the pure oxidized lead compounds.

EARTHENWARE GLAZES WITHOUT LEAD OR BORIC ACID.—E. Berdel (*Ker. Rund.*, 25, 88, 1917). A preliminary communication. In general, for cones 1—6, the following may be taken as the limits, using the minimum content of alkali: $0{\cdot}3(KNa)_2O$.0—$0{\cdot}15ZnO$.$0{\cdot}1$—$0{\cdot}2MgO$, about $0{\cdot}5BaO$.$0{\cdot}14$–$0{\cdot}18Al_2O_3$.$1{\cdot}4$—$1{\cdot}8SiO_2$. The following is an example: $0{\cdot}2K_2O$.$0{\cdot}1Na_2O$.$0{\cdot}1ZnO$.$0{\cdot}1MgO$.$0{\cdot}5BaO$.$0{\cdot}16Al_2O_3$.$1{\cdot}52SiO_2$. The frit for this may be made up of 559 felspar, 138 anhydrous potash, 106 calcined soda, 81 zinc oxide, 84 magnesite, 987 barium carbonate, 480 quartz. For the mill is taken 2,080 frit, 155 Zettlitz kaolin.

EARTHENWARE GLAZES WITHOUT LEAD OR BORIC ACID.—E. Berdel (*Ker. Rund.*, 25, 199, 1917). Relates to glazes to be fired between cones 1 and 6 or 3a to 6a. The chief points of view were as follows: (1) To limit the number of the alkalies. (Tostmann used high alkali content for the same object.) The chief reason was, by working against the decomposability of the frit by water and acids, to preserve the better melting influence of the alkalies through the necessary high alumina number. But with the introduction of soda and potash, a determination of their content (at least a dry determination) is necessary, for differences of several per cent. in these glazes have perceptible influence. (2) The content in alumina and silica must be carefully tested. Both give the glaze good properties for resisting chemical influences and as regards crazing, and the alumina particularly also against devitrification. They cause a difficult refractoriness of the frit, which again opposes the existing arrangement of the frit-kiln. But many factories had to complain of similar difficulties with lead glazes. The highest contents of alumina and silica within the limits mentioned in the author's preliminary communication (see above) were chosen. This increase of alumina and silica was found necessary for certain results, when a slight increase of the lower temperature limit must be undertaken. (3) Baryta was especially used as vitrifying material, whilst lime should chiefly check crazing. As lime, magnesite, and zinc oxide are increased against baryta and alkalies, peculiar transparent matt glazes are obtained which bring underglaze colours to better development. (4) The glazes can be used for a temperature range between several cones. Trials were fired between cones 2 and 4 (4a and 6a according to the more recent scale), that is, with the lower limit somewhat higher than in earlier communications. Trials modified for a lower firing temperature by the introduction of a high alkali content (especially of the easily fusible soda) inevitably showed the fault of crazing. (5) The body on which the glazes were melted is a hard magnesite earthenware, fired at cone 6a, made up from 15 parts by weight of Zettlitz kaolin, 15 Löthain clay, 15 kaolin clay M (from Grünstadt), 15 Dölau kaolin, 10 Kemmlitz kaolin, 23 Dörentrup quartz, and 7 magnesite. The introduction of magnesite as flux in place of the more usual felspar and calcspar has no direct connection with the glaze trials. Such bodies showed favourable properties towards other glazes. The glazes were fired in the round ovens of the industry, and had the compositions:—

(51)	$0{\cdot}25K_2O.0{\cdot}20Na_2O.0{\cdot}05MgO.0{\cdot}05ZnO.0{\cdot}45BaO.$	$0{\cdot}17Al_2O_3.1{\cdot}6SiO_2$
(52)	$0{\cdot}05K_2O.0{\cdot}25Na_2O.0{\cdot}20CaO.0{\cdot}10MgO.0{\cdot}10ZnO.0{\cdot}30BaO.$	$0{\cdot}17Al_2O_3.1{\cdot}9SiO_2$
(53)	$0{\cdot}13K_2O.0{\cdot}15Na_2O.0{\cdot}25CaO.0{\cdot}47BaO.$	$0{\cdot}17Al_2O_3.2{\cdot}0SiO_2$
(54)	$0{\cdot}12K_2O.0{\cdot}12Na_2O.0{\cdot}25CaO.0{\cdot}04MgO.0{\cdot}03ZnO.0{\cdot}44BaO.$	$0{\cdot}17Al_2O_3.2{\cdot}0SiO_2$
(338c)	$0{\cdot}2ZnO.0{\cdot}1MgO.0{\cdot}7BaO.$	$0{\cdot}1Al_2O_3.1{\cdot}4SiO_2$
(36)	$0{\cdot}10K_2O.0{\cdot}20CaO.0{\cdot}10MgO.0{\cdot}10ZnO.0{\cdot}50BaO.$	$0{\cdot}17Al_2O_3.1{\cdot}6SiO_2$
(338a)	$0{\cdot}20ZnO.0{\cdot}3MgO.0{\cdot}50BaO.$	$0{\cdot}1Al_2O_3.1{\cdot}4SiO_2$

They were made up as follows:—

	Felspar	Anhydrous Potash	Calcined Soda	Magnesite	Zinc Oxide	Barium Carbonate	Quartz	Calcspar	Zettlitz Kaolin	For Mill: Frit	For Mill: Zettlitz Koalin
(51)	55·9	20·7	21·2	4·2	4·1	88·7	51·6	—	—	209·0	18·1
(52)	28·0	—	26·5	8·4	8·1	59·1	81·6	20·0	13·0	207·3	18·1
(53)	55·9	4·1	15·9	—	—	92·6	75·6	25·0	—	229·3	18·1
(54)	55·9	2·8	12·7	3·4	2·4	86·7	75·6	25·0	—	226·1	18·1
(338c)	—	—	—	8·4	16·2	137·9	72·0	—	13·0	210·5	13·0
(36)	55·9	—	—	8·4	8·1	98·5	51·6	20·0	—	207·3	18·1
(338a)	—	—	—	25·2	16·2	98·5	72·0	—	13·0	187·9	13·0

The two last are matt glazes—(36) and (338a)—which give remarkable effects.

Glaze (51) was bright and shining, but owing to high alkali content and absence of lime it showed a tendency to craze. (52) was about the same as (51) for lustre, etc., but better as regards crazing. In (53) the further increase of silica increases the resistance to chemical decomposition and to crazing, while the absence of the costly zinc oxide makes it more suitable for practice. (54) is the finest and most promising glaze. (338c) came out surprisingly well in a muffle, but proved somewhat uncertain in the round oven. Other trials with zinc-barium glazes without alkalies are in progress. Underglaze colour trials with leadless glazes fired in earthenware round ovens at cone 4a came out particularly bright.

POTTERY GLAZES.—W. P. Edwards, W. H. Edwards, and W. Mollart (*Pat. J.*, No. 1,545, 1918). Pat. No. 117,047, Feb. 13th, 1918. Consists in mixing ordinary potter's glaze with calcined sea-shells or the shells of fish. Two ounces of calcined shell may be mixed with water into a thick paste and then distributed gradually into 1 cwt. of ordinary potter's glaze; after standing for some time the whole is thoroughly mixed for about five minutes. Sufficient water is then added to bring the mixture to the right strength. It is stated that the calcined shell produces a thickening of the glaze which in the case of lead glazes permits of the lead being considerably reduced in strength.

VII.—COLOURS & DECORATIVE PROCESSES.

THE SCHOOP METAL-SPRAYING PROCESS.—M. P. (*Tonind. Ztg.*, 41, 913, 1917). A review of a book by H. Günther and M. U. Schoop, in which the process is described.

STENCILS FOR UNDERGLAZE PAINTING.—E. Block (*Ker. Rund.*, 25, 9, 1917). A short article pointing out the suitability of stencils for producing cheap decoration.

EFFECT OF MAGNESIA GLAZES ON UNDERGLAZE COLOURS.—(*Ker. Rund.*, 25, 279, 1917). Translated from C. P. Shah's paper in TRANS., 17, 106, 1917.

PLATINIZING POTTERY, Etc.—F. J. Kettel, A. Gasch, and T. A. Dean (*Pat. J.*, No. 1,547, 1918). Pat. No. 117,432, May 13th, 1918. The article is covered with a solution or emulsion consisting of platinum chloride (3 grams), glycerol (12 c.c.) and phenyl hydrazine (7 drops), heated to 850°—900° C. to reduce the platinum to the metallic state, and subsequently cooled gradually under ordinary atmospheric conditions. In preparing the solution or emulsion, the platinum chloride is dissolved in the least possible quantity of water, the glycerol is added, and the mixture is heated on a water bath (for 1½ hours after reaching boiling point); the phenyl hydrazine in then added slowly drop by drop and the mixture stirred. Heating is continued until frothing ceases (about 3 hours), or the liquid may be poured away from the froth.

ANTIMONY OXIDE.—E. F. Morris and T. N. C. Nevill (*Pat. J.*, No. 1,560, 1918). Pat. Nos. 119,711 and 119,712, Oct. 17th, 1917. Relate to methods of purification from acid substances.

VIII.—COSTS, MANAGEMENT, ORGANIZATION COMMERCIAL REPORTS.

COST OF FIRING.—F. H. Haase (*Tonind. Ztg.*, 41, 193, 1917). A brief discussion of the question as regards claywares in general.

GUARANTEE OF REFRACTORY PRODUCTS.—V. O. (*Tonind. Ztg.*, 41, 883, 1917). A discussion of the question, particularly as regards refractoriness and crushing strength.

CERAMICS AND THE WAR.—E. W. Washburn (*Met. Chem. Eng.*, 18, 253, 1918). The British requirements in chemical glassware, heat-resisting glass (for miners' lamps) and optical glass, and the inadequate home supplies of glass generally after the outbreak of war are briefly alluded to, and the means adopted to remedy the deficiencies. The same problem faced America later.

Refractory materials presented another problem of vital importance, as they are indispensable in all industries where high temperatures are employed, especially in metallurgical industries and others concerned with the production of munitions of war. Among the porcelain refractories are the special electrical insulators for high-tension transmission lines, and the insulators for ordinary voltages in buildings, cars, and on ships; sanitary porcelain; the porcelain used by chemists in the form of crucibles, etc.; the porcelain used in protecting pyrometer tubes; and the porcelain spark plugs so important in aeroplanes (bad plugs deteriorating rapidly under the influence of the high temperatures they are subjected to during the operation of the engine, and so limiting the time the aeroplane can stay in the air). The following are other important ceramic products in time of war:—

1. Enamelled iron products, such as autoclaves, kettles, and evaporators, which are used in ammunition manufacture. The manufacture of an enamelled lining which will withstand the pressures, temperatures, and chemical action to which it is subjected in these processes is quite a problem. Enamelled cooking vessels for the army canteens and kitchens may also be mentioned.

2. Abrasive wheels, largely used in the manufacture of artillery. The proper bonding material for use in the manufacture of such wheels is a ceramic problem still needing considerable investigation.

3. The purification and treatment of ceramic raw materials (clays, sand, bauxite, etc.), in order to adapt them for the needs of the manufacturer, is also one of the most important ceramic subjects at the present time.

Emphasis is laid on the great need for scientifically trained ceramic chemists and ceramic engineers.

PRODUCTION COSTS AND SELLING PRICES.—F. Schünhoff (*Deut. Töpf.-Zieg.-Ztg.*, 48, 308, 1917). A brief review of the question as regards the brickmaking industry.

COST PRICE CALCULATION.—O. (*Deut. Töpf.-Zieg.-Ztg.*, 48, 321, 1917). A discussion of the question with special reference to brickmaking, and explained by means of figures taken from practice.

CORRECT CALCULATION.—F. J. (*Deut. Töpf.-Zieg.-Ztg.*, 48, 337, 1917). An article dealing largely with certain fallacies which arise in connection with brickmaking.

X.—GLASS

NITRE SUBSTITUTE.—L. Springer (*Ker. Rund.*, 25, 1, 1917). Reproduced from *Sprech.*, (Dec., 1916). A report on trials with a new preparation used by Schott & Co., of Jena, the composition of which is not given. The material in question is a very good decolorant for glass, and alone without addition of oxidizing or decolorizing substance it produces with a soda-lime glass an almost pure white very clear glass. Hence only a very small quantity of the used decolorizing substance is added in any case. The preparation also acts well with potash-lime glass, with a Glauber's salt glass, and even in lead glasses it shows a decolorizing action.

For a final decision on this substitute a series of trials on a large scale are still necessary, but according to these experiments it can certainly be recommended.

SMALL TANK FURNACES.—H. Schall (*Ker. Rund.*, 25, 47, 1917). An illustrated account of a small plant suitable for use when the output of glass is comparatively small.

SODIUM BISULPHATE INSTEAD OF GLAUBER'S SALT.—L. Springer (*Ker. Rund.*, 25, 67, 1917). The properties of the two substances are compared, and some disadvantages of Glauber's salt referred to. The necessity of knowing the composition of new materials, before use, is insisted on.

SELENIUM AS DECOLORISER.—W. Frommel (*Ker. Rund.*, 25, 95, 102, 107, 1917). A general account of the occurrence, production, and properties of selenium is given, and also of the optical considerations which necessitate the use of decolorisers. Black and red selenium, and sodium selenite are used for the purpose. It has been ascertained that the green colouring effect of 1 kg. iron oxide is compensated by 0·208 g. selenium (or 0·0208 per cent.), and as a glass batch rarely contains more than 0·2 per cent. of iron oxide, the quantity of selenium necessary would not usually exceed 0·00416 per cent. of the batch, or if sodium selenite be used, rather more than double that amount would be required.

The use of selenium as a decoloriser was originally protected by German patents 63,558, 78,565, and 88,615.

POLYCHROMATIC INSCRIPTIONS OR DECORATIONS ON GLASS.—(*Ker. Rund.*, 25, 114, 1917). A short account of a method depending on covering the surface of the glass with suitable paper (as oil paper), using dextrin or other suitable adhesive, then if necessary tracing or transferring outlines so that the letters or decorations, etc., can be cut out, applying the ground colour on the glass, soaking the rest of the paper and the adhesive with water to remove them; and finally applying any desired colour or gold leaf. A process for matt gold is also described, and an Austrian decoration process.

INFLUENCE OF ALUMINA ON FUSIBILITY OF GLASSES.—F. Singer (*Ker. Rund.*, 25, 142, 153, 160, 172, 184, 195, 201, 206, 1917). A continuation of previous work (*Ker. Rund.*, 23, 65, 78, 95, 103, 1915), and also a reply to the criticism of L. Springer (23, 271, 280, 1915). In the further trials the author found that the melts without alumina were the most difficult to fuse, addition of alumina made the melt more fusible (a striking effect being produced by only 0·05 molecule Al_2O_3), the fusibility increased regularly with the gradual increase in alumina up to $0{\cdot}20Al_2O_3$, and the result was apparently the same whether the alumina were introduced as hydroxide or as kaolin.

As examples of more complex glasses a glass of the following composition was made up, and a similar one with the addition of 0·15 mol. alumina: $0{\cdot}2Na_2O.0{\cdot}3K_2O.0{\cdot}1MgO.0{\cdot}2CaO.0{\cdot}1SrO.0{\cdot}1BaO.3{\cdot}0SiO_2$. With these also the glass containing alumina was the more fusible.

The author considers that, though the effect of alumina may not be the same for different kinds of glass (lead crystal, phosphate, or borate glasses, etc.), the results would differ in degree rather than in kind, and the limits for the advantageous use of alumina would be different in the different kinds of glass.

Quotations are given from various publications bearing on the effect of alumina in pottery glazes, which support the author's view that up to a certain limit alumina exercises a fluxing action. A small quantity of alumina in heavy lead glasses considerably increases the resistant qualities of the glass without materially affecting the fusibility.

INFLUENCE OF ALUMINA ON THE FUSIBILITY OF GLASSES.—L. Springer (*Ker. Rund.*, 25, 283, 289, 293, 300, 305, 1917). An elaborate reply, largely based on experimental evidence, to F. Singer's recent contribution on the same subject (*Ker. Rund.*, 25, 142, etc., 1917). The author concludes that the influence of alumina on fusibility of glass is greatly affected by the composition of the glass and other variable factors, and cannot be definitely laid down.

MACHINES IN GLASS WORKS.—F. M. (*Ker. Rund.*, 25, 173, 190, 1917). A general survey of the possibilities as regards the use of mechanical appliances in the different stages of glass manufacture, and a plea for the extended employment of machines wherever possible.

DECORATION OF ORNAMENTAL GLASS OBJECTS.—(*Ker. Rund.*, 25, 244, 1917). Has reference to silvering, gilding, and similar depositions of copper.

GLASS FOR OPTICAL AND OTHER PURPOSES IN ENGLAND.—(*Ker. Rund.*, 25, 273, 1917). Translated from the second annual report of the Council for Scientific and Industrial Research.

RING SHIELD FOR GLASS-DRAWING APPARATUS.—W. L. Monro, Can. Pat. 175,284, Feb. 20th, 1917. The ring surrounds the drawing point and dips into the glass bath, being held in position so as to supply a symmetrical mass of glass around the article at the drawing point.

CRUCIBLE FURNACES.—C. M. Stein et Cie (*Pat. J.*, No. 1,502, 1917). Pat. No. 109,243, Aug. 29th, 1916. Gas passes to a central burner, and air is received through radial passages from one or more external regenerators. The products of combustion escape by openings in the pillars of the crucible chamber to flues leading to the regenerators.

GLASS-BLOWING Etc.—F. O'Neill (*Pat. J.*, No. 1,502, 1917). Pat. No. 109,314, Sept. 13th, 1916. Relates to a semi-automatic machine for making glass bottles, etc.

GLASS FURNACES.—Tyne Glass Works and A. B. Roxburgh (*Pat. J.*, No. 1,503, 1917). Pat. No. 109,541, Nov. 24th, 1916. The furnace is fired by gas passing from a combined producer by an outlet below the surface of the fuel, and a dust trap is placed between the producer and the furnace.

GLASS-BLOWING MACHINES.—General Electric Co. (*Pat. J.*, No. 1,503, 1917). Pat. No. 109,544, Dec. 5th, 1916. Relates to machines for blowing glass bulbs, etc., from lengths of glass tubing and of the kind described in Specifications 1,033/82 and 12,824/11, in which the tube is supported at its ends in chucks (one movable).

GLASS-BLOWING MACHINES.—Westlake European Machine Co. (*Pat. J.*, No. 1,503, 1917). Pat. No. 109,587, Sept. 12th, 1916). Relates to automatic glass-blowing machines of the type described in Specification 26,222/11 for making electric lamp bulbs, etc., and comprises improvements in the gathering and cut-off mechanisms.

DELIVERING MOLTEN METAL; ROLLING.—J. H. McKelvey and C. F. Ryan (*Pat. J.*, No. 1,504, 1917). Pat. No. 109,634, Aug. 15th, 1916. Relates to plate glass. The molten glass is delivered by special contrivances from a melting furnace into an independently heated collecting chamber or furnace, from which the glass is poured directly on to a rolling table.

DRAWING GLASS.—D. Webb (*Pat. J.*, No. 1,504, 1917). Pat. No. 109,711, Dec. 13th, 1916. In the manufacture of glass tubes for gauge glasses, miners' lamps, etc., the inner surface of the tube is cooled as quickly as the outer surface, so as to harden the internal surface, by blowing a current of cold or cooled air through the tube from end to end during or immediately after the drawing operation.

DELIVERING MOLTEN METAL.—O. M. Tucker and W. A. Reeves (*Pat. J.*, No. 1,504, 1917). Pat. No. 109,782, Sept. 16th, 1916. Relates to a method of delivering molten metal through an outlet so that a gob of the required size can be cut off and delivered to the mould without creasing or folding.

DRAWING GLASS TUBING.—General Electric Co. (*Pat. J.*, 1,505, 1917). Pat. No. 109,843, Sept. 27th, 1916. A float for use in drawing glass tubing by means of the machine described in Specification 17,602/13 consists of a plate of graphite or other refractory material with a central annular opening through which the tubing is drawn.

GLASS-BLOWING.—Westlake European Machine Co. (*Pat. J.*, 1,507, 1917). Pat. No. 110,305, Sept. 12th, 1916. Relates to air-controlling mechanism for glass-blowing machines of the kind described in Specification 26,222/11 for making electric lamp bulbs, etc.

FORMING LAMP GLASSES, Etc.—L. N. Bruner and S. D. Olsen (*Pat. J.* 1,508, 1917). Pat. No. 110,390, Oct. 17th, 1916. Relates to the manufacture of glass cylinders, such as are used for lamp chimneys in a centrifugal moulding machine.

DRAWING GLASS.—Libbey Glass Co. (*Pat. J.*, No. 1,509, 1917). Pat. No. 110,642, Nov. 29th, 1916. A method of drawing molten material such as glass, in either hollow or solid cylindrical form, consists in directing a stream of the molten material on to the exterior surface of a rotating member and drawing the material from the said member. The molten glass is placed in a trough above a furnace, and after flowing down a step to eliminate air bubbles, passes beneath an adjustable gate and flows in a small stream on to the exterior of a rotating blowpipe situated in an independently heated chamber.

GLASS-BLOWING.—Westlake European Machine Co. (*Pat. J.*, No. 1,512, 1918). Pat. No. 111,122, Sept. 12th, 1916. Relates to the type of automatic glass-blowing machine for making electric lamp bulbs, etc., described in Specifications 26,222/11 and 26,224/11, wherein a series of gathering mechanisms carried on a rotary frame successively suck up metal from a furnace into blank moulds and transfer the blanks thus formed to their respective blowing-spindles.

GLASS-BLOWING.—A. E. Clegg (*Pat. J.*, No. 1,513, 1918). Pat. No. 111,231, April 10th, 1917. Refers to machines for blowing glass bottles.

DRAWING GLASS.—Libbey Glass Co. (*Pat. J.*, No. 1,514, 1918). Pat. No. 111,521, Nov. 29th, 1916. Relates to apparatus for drawing molten glass or like material in either hollow or solid cylindrical form in accordance with the process described in Specification 110,642, and comprises an inclined forming-mandrel or blowpipe on to which the molten material flows and around which it is evenly distributed and from which it is drawn lengthways. The mandrel may be adjusted longitudinally whilst in action.

STRENGTHENED GLASS.—S. Goldreich, C. A. McKerrow, and Splinterless Anti-Mist Glass Syndicate (*Pat. J.*, No. 1,514, 1918). Pat. No. 111,539, Dec. 2nd, 1916. Refers to strengthened glass comprising two sheets of glass and an interposed sheet of celluloid.

GLASS-GATHERING DEVICE.—A. Wilzin (*Pat. J.*, No. 1,515, 1918). Pat. No. 111,701, Dec. 4th, 1916. Relates to a modification of the automatic glass-gathering device of Specification 3,146/15.

GLASS SHAPING AND BLOWING MACHINES.—A. Wilzin (*Pat. J.*, No. 1,516, 1918). Pat. No. 111,868, Oct. 11th, 1916. Comprises automatically controlled means for (1) submitting the parison to an automatically controlled temperature equalization process, the duration of which may be varied at will by means of a controlling device with adjustable dogs, etc., which connect and disconnect the machine with the source of power, (2) forcing the glass into intimate contact with the walls of the parison mould, and (3) expediting the stretching of the parison. Reference is made to Specifications 7,183/12, 20,299/13, and 3,146/15.

GATHERING GLASS.—C. F. Cox (*Pat. J.*, No. 1,516, 1918). Pat. No. 111,890, Dec. 11th, 1916. A circulation of the glass is caused so as to avoid the collecting of chilled glass at the gathering place. The circulation may be produced in different ways.

MOULDING GLASS, Etc.—Soc. Anon. des Verreries de Fauquez (*Pat. J.*, No. 1,516, 1918). Pat. No. 111,920, Dec. 21st, 1916. An apparatus for moulding hollow glass articles having internal projections.

GLASS-BLOWING.—E. Roibant (*Pat. J.*, No. 1,517, 1918). Pat. No. 112,007, Sept. 14th, 1917. The parison and finishing moulds of a glass-blowing machine are hinged on separate and fixed axes and have opening and closing movements only, and the opening or closing movement of the parison mould and the closing or opening movement of the finishing mould commence and finish at the same time.

WIRED GLASS.—Chance Bros. & Co. and E. Beetlestone (*Pat. J.*, No. 1,517, 1918). Pat. No. 112,099, June 7th, 1917. Rollers for embedding wire in glass are made with a series of projections in place of the continuous annular ribs usually employed.

GLASS-BLOWING MACHINES.—Westlake European Machine Co. (*Pat. J.*, No. 1,518, 1918). Pat. No. 112,221, Sept. 12th, 1916. Relates to glass-blowing machines of the type described in Specification 26,222/11 for making electric lamp bulbs, etc., and consists in providing means for varying during the operation of the machine the intensity of the vacuum produced in the gathering mould while the blank is held therein and before it is delivered to the spindle.

GLASS-BLOWING MACHINES.—A. Kadow and Westlake European Machine Co. (*Pat. J.*, No. 1,519, 1918). Pat. No. 112,258, June 18th, 1917. Relates to machines for making electric lamp bulbs, etc., of the type described in Specification 26,222/11.

GATHERING MOLTEN METAL.—A. Kadow and Westlake European Machine Co. (*Pat. J.*, No. 1,521, 1918). Pat. No. 112,613, June 18th, 1917. Relates to gathering apparatus of the kind described in Specification 26,222/11, in which one or more gathering rams or devices are carried on a rotating structure and periodically brought opposite to and thrust into the working opening of a stationary glass furnace with a closed top, and consists in making the gather by a radial movement of the ram without interrupting the continuous rotary movement of the ram and without arresting the rotary movement of the supporting structure.

GLASS-BLOWING.—A. E. Clegg (*Pat. J.*, No. 1,521, 1918). Pat. No. 112,706, April 10th, 1917. Relates to a glass bottle-blowing machine in which compressed air is supplied through a plunger which is caused by spring-influenced means to make a tight joint with the ring-mould while the bottle is in the finishing mould. A hand-operated cam and spring mechanism are adapted to press the plunger downwards in an elastic manner.

DELIVERING MOLTEN GLASS.—W. J. Miller (*Pat. J.*, No. 1,523, 1918). Pat. No. 112,947, Jan. 24th, 1918. Relates to means for controlling the flow of glass from the delivery outlet of the melting tank in order to give time for changing the receiving mould and to remelt the scars formed by shearing.

GLASS BOTTLES AND JARS, Etc.—R. E. McCauley (*Pat. J.*, No. 1,527, 1918). Pat. No. 113,665, March 2nd, 1917. Relates to a method of, and means for, controlling the supply of molten glass from a furnace or tank to the parison moulds used in the manufacture of bottles, jars, etc.

GATHERING MOLTEN METAL.—J. Forster (*Pat. J.*, No. 1,528, 1918). Pat. No. 113,797, Dec. 14th, 1916. Relates to machines for making feeding bottles, etc., with molten glass. A gathering-head or carrier—arranged so as

to be rocked in the vertical plane—sucks up the glass from a furnace or tank, and is then moved to the receiving part of the machine, where the charge of glass is discharged by air pressure.

DRAWING GLASS CANE AND TUBING.—General Electric Co. (*Pat. J.*, No. 1,528, 1918). Pat. No. 113,892, June 12th, 1917. Relates to apparatus for drawing cane glass and tubing of the form described in Specification 105,285, and consists of driving the chilling, cutting, and delivery devices through mechanism independent of the chain conveyer, in order that the machine may be driven at greater speed.

ANNEALING GLASS, PORCELAIN, Etc.—A. Hilger, Ltd., and F. Twyman (*Pat. J.*, No. 1,530, 1918). Pat. No. 114,183, March 19th, 1917. In annealing glass, porcelain, and some metals, the progress or completion of the process is indicated by means of a rod of the substance to be annealed, the rod being maintained under stress.

GLASS-BLOWING MACHINE.—E. H. Langwell and E. Durand (*Pat. J.*, No. 1,530, 1918). Pat. No. 114,193, March 21st, 1917. Relates to a manually-operated machine for blowing glass bottles, etc., and of the kind in which the suction and preliminary blowing in the parison mould are effected by two pistons working in unison in separate cylinders, to one of which compressed air is admitted by a four-port valve.

GLASS-BLOWING.—T. B. Kitson and G. O. Tague (*Pat. J.*, No. 1,532, 1918). Pat. No. 114,477, April 5th, 1917. In apparatus for making glass bottles, jars, etc., in which the parison and finishing moulds are arranged alternately round a revolving table, all the operations of suction and blowing and of the opening and closing of the moulds, except the transfer of the parison, are effected automatically and controlled by two cams only.

WITHDRAWING GLASS.—R. E. McCauley (*Pat. J.*, No. 1,533, 1918). Pat. No. 114,583, Oct. 20th, 1917. The glass flows from the tank into a detachable extension, the bottom of which is provided with a nozzle, the upper edge of the nozzle rising above the level of the glass. A vertical cylinder is slidably mounted in the top of the extension and can be raised and lowered by a hand-lever pivoted in lugs. Two pipes communicate with the upper end of the cylinder, and are connected respectively with a source of compressed air, or the atmosphere, and to a suction pump. The glass is drawn into the cylinder, and is discharged when the valves are reversed.

GLASS-BLOWING.—W. Forster (*Pat. J.*, No. 1,533, 1918). Pat. No. 114,678, April 21st, 1917. Relates to machines for making glass bottles, etc., and of the type having a revolving frame or plate carrying parison moulds on opposite sides of its horizontal axis and two sets of neck or mouth moulds carried on the terminals of a hollow double arm.

HOLLOW GLASSWARE.—Shawbruner, Ltd., G. C. Pyle, and G. C. Dager (*Pat. J.*, No. 1,533, 1918). Pat. No. 114,709, June 1st, 1917. In apparatus for making hollow glassware, the parison is held at one end by the neck-mould and at the other end by a centring device or bottom mould, which serves to support the parison during its transfer from the parison mould to the blowing mould and whilst being blown in the latter.

DELIVERING MOLTEN METAL.—R. E. McCauley (*Pat. J.*, No. 1,553, 1918). Pat. No. 118,581, May 21st, 1918. Relates to arrangements in connection with glass-melting tanks to secure that the metal delivered is of uniform character by preventing its being unequally chilled at the cooler end of the tank.

DELIVERING MOLTEN METAL.—R. E. McCauley (*Pat. J.*, No. 1,554, 1918). Pat. No. 118,585, May 31st, 1918. Relates to means for conveying

molten metal from the melting tank to machines, and consists of an arrangement by which separate machines may be supplied in succession.

DRAWING GLASS.—A. E. Spinasse (*Pat. J.*, No. 1,534, 1918). Pat. No. 114,819, Nov. 26th, 1917. In drawing glass cylinders, the hollow bait used is coated on the glass-contacting surfaces with an adhesion-preventing substance. The bait is preheated to a temperature at which molten glass adheres to it, and the coating may be applied before, but is preferably applied after heating. Resin, tallow, oils, and waxes, or compounds of these materials, are mentioned as suitable substances for coating an iron bait heated to about 400° F., and powdered lime, magnesia, etc., for a bait heated to about 900° F. Lime in the form of paint, whitewash, or some oily emulsion of clay, paint, lime, or graphite, which may be in powdered or pasty form, is stated to be most suitable. The coating may be shaped or moulded into the form of an envelope and slipped on to the bait. The bait may be made of cast-iron, chrome or nickel steel, etc.

DRAWING SHEET GLASS.—Libbey-Owens Sheet Glass Co. (*Pat. J.*, No. 1,535, 1918). Pat. No. 114,977, Oct. 4th, 1917. Relates to apparatus of the type in which a sheet of glass is drawn upwards and bent round a roller so as to bring it into a horizontal position and is then carried forward between endless chains and delivered to the leer. The melting furnace is formed with a shallow extension through which the metal passes to the drawing trough. The edges of the drawn sheet pass between pairs of knurled rollers which regulate the thickness and it is bent over a cooled roller from which it passes over two other rollers between gripping bars carried by endless chains.

GLASS FURNACE.—A. F. Peeters (*Pat. J.*, No. 1,542, 1918). Pat. No. 116,477, Feb. 11th, 1918. In a tank glass-melting furnace having melting and working compartments, the burner or inlet for the heating gases is situated at the end of the working compartment, and the outlet flue at the end of the melting compartment.

SHEET GLASS.—T. J. McCoy (*Pat. J.*, No. 1,545, 1918). Pat. No. 117,194, Oct. 29th, 1917. Relates to apparatus for forming sheet glass in which the metal is delivered from the furnace in the form of a sheet which, whilst still plastic, is received by a conveyer which carries it away.

DISCHARGING GLASS.—E. Roirant (*Pat. J.*, No. 1,547, 1918). Pat. No. 117,452, June 27th, 1918. Glass is discharged from a melting furnace into a receptacle which can be moved from its receiving-position within a chamber adjoining the furnace to the gathering point.

GLASS FOR WINDOWS, LAMPS, Etc.—Mississippi Glass Co. and C. J. Gundlach (*Pat. J.*, No. 1,552, 1918). Pat. No. 118,269, April 3rd, 1918. Relates to glass for windows, lamps, etc., with surface markings to distribute light rays to prevent glare. The glass is formed with a series of minute depressions on one surface, as produced by cross-ribbing the glass. The glass is fire-polished on the side with the depressions.

MOULDING GLASS.—W. J. Miller (*Pat. J.*, No. 1,552, 1918). Pat. No. 118,282, Aug. 8th, 1918. Relates to a rotary table moulding-machine actuated by fluid pressure.

GLASS.—Corning Glass Works.—(*Pat. J.*, No. 1,553, 1918). Pat. Nos. 118,397 and 118,398, April 15th, 1918. Relates to the production of glass capable of absorbing ultra-violet rays and as nearly colourless as possible, and consists in adding to the glass composition titanium oxide and an oxidizing salt, or vanadium (preferably in an oxidized form). The titanium or vanadium compound may be used in conjunction with cerium oxide, etc. Nitre may be added to prevent reduction of the oxides.

NOTES ON THE FORMATION OF CERTAIN ROCK MINERALS IN AND ABOUT GLASS FURNACES.—G. W. Wilson (*J. Soc. Glass. Tech.*, 2, 177, 1918). The formation of several minerals either by the crystallization of molten glass or by the action of the latter on refractories, etc., is described. A furnace containing about 70 tons of glass burst and the mass of molten material cooled slowly for about five days, with the result that wollastonite, tridymite, quartz and augite crystallized out. The wollastonite ($CaSiO_3$) was the β or low temperature form, thus indicating that crystallization commenced below 1,200° C., the transition point between the α and β forms of calcium metasilicate. The formation of the tridymite followed that of the wollastonite. Quartz and augite were found in thin strings of glass, penetrating cracks in the brickwork. Two types of veins are found: (*a*) ordinary green glass and (*b*) amethyst-coloured glass. Chemical analyses of the veins and contact bands show a progressive diminution in lime and magnesia and an increase in manganese passing from the normal glass to the contact zones. The rim in contact with unaltered brick has recrystallized mainly as felspar. The amethyst material contains wollastonite and a pyroxene high in silicate of manganese, as well as occasional crystals of quartz. This verifies the prevalent idea that manganese tends to sink to the bottom of the tank.

By the action of the glass on fragments of limestone the minerals formed include wollastonite, augite, melilite, and the compound $3CaO.2SiO_2$. The fluxes from the glass and the furnace gases react with the aluminous refractories to form sillimanite (Al_2SiO_5), corundum (Al_2O_3), magnetite, biotite and felspar. The biotite is apparently a soda-bearing variety and must also be anhydrous.

With reference to the occurrence of sillimanite and corundum, it is found that the former first develops in the contact layer but is afterwards dissolved, part of the alumina being absorbed in the glass and the remainder reprecipitated as corundum. The white porcellanic layer found round the refractories is often packed with sillimanite crystals. Sillimanite is only developed in pots which have undergone vitrification, and its presence, especially on the inner surfaces, is highly beneficial, as it reduces the liability to corrosion and thereby lengthens the life of the pot or block. In practice, clays as highly aluminous as possible should be used, but at the same time the vitrification temperature should be in the neighbourhood of the furnace temperatures. A.S.

XI.—CEMENTS, MORTARS, CONCRETE, Etc.

PROPERTIES OF CEMENTS.—K. Reinbold (*Tonind. Ztg.*, 41, 14, 1917). Based on a report by Burchartz in *Heft 1 der Mitteilungen aus dem Königlichen Materialprüfungsamt, 1915*, showing certain physical and mechanical tests of Portland and other cements.

PREPARATION OF CHAMOTTE MORTAR.—A. Siebel (*Tonind. Ztg.*, 41, 27, 1917).

BURNING OF CEMENT IN SHAFT KILNS.—R. Tascher (*Tonind. Ztg.*, 41, 39, 1917). An account of practical experiences.

CEMENT IN WATER CONTAINING SULPHURIC ACID.—Nitzsche (*Tonind. Ztg.*, 41, 57, 1917). A discussion between Dr. Nitzsche and Dr. Röder, reference being made to an article by the latter in No. 117 of the *Tonind. Ztg.*

PLASTER IN INDUSTRY.—B. Rosz (*Tonind. Ztg.*, 41, 63, 1917). A brief review of the uses to which plaster is put in connection with building, moulds, pigments (finely ground under the trade name annalin), glass-making, paper-making (under the name lenzin), Portland cement industry, metal casting (as moulds and models), chemical industry, etc. Annalin and lenzin do not harden with water like ordinary plaster.

BLAST-FURNACE CEMENTS.—H. Nitzsche (*Tonind. Ztg.*, 41, 112, 119, 1917). An investigation of the behaviour of several of these cements, using tap water, and water containing calcium sulphate, sodium sulphate, or sulphuric acid.

INFLUENCE OF FINE GRINDING ON PORTLAND CEMENT.—H. Kühl (*Tonind. Ztg.*, 41, 197, 1917). Results of tests are shown in a table. The weight of a litre always decreases with increasing fineness. The water required for production of normal quality with increasing fineness increases up to about 30 per cent. more than the quantity required for the most coarsely ground cement (with 60 per cent. residue), and with increasing fineness the cement should always set more rapidly. There is a sudden transition in the time of setting between cement with 15 per cent. residue (on sieve with 4,900 meshes per sq. cm.) and cement with 10 per cent. residue, the former taking 210 to 345 minutes for beginning and ending respectively, and the latter only 7 to 9 minutes, the water addition being $21\frac{1}{4}$ and $21\frac{3}{4}$ per cent. respectively. The period was still shorter with smaller proportions of residue. Tests of tensile and crushing strength, after 3, 7, and 28 days, and even longer periods, showed in general great increase of strength with increasing fineness, but with some irregularities when the residue got below 20 per cent.

DETERMINATION OF SLAG CONTENT IN CEMENTS.—E. Sack (*Tonind. Ztg.*, 41, 227, 238, 1917). The common method of separating the ingredients by introducing the material into a liquid of suitable specific gravity has been shown to be liable to errors of ± 5 per cent. A. Guttmann devised a method in which the microscope is used, the particles of clinker and slag being sharply distinguished with magnification of only 50 to 100, and claims that it gives more accurate results.

FINE GRINDING OF PORTLAND CEMENT.—A. B. H. (*Tonind. Ztg.*, 41, 383, 1917). Cement has long been produced on a large scale with a far smaller residue than 15 per cent. on the 5,000-mesh sieve without being quick-setting and without too high an addition of plaster; reference is made to Prüfungszeugnis No. 52,767, Abt. 2, No. 11,193 of the Kgl. Materialprüfungsamtes of 9th Nov., 1910, for proof. The cement had a residue of 0·6 per cent. on the 5,000-mesh sieve, a water requirement with pure cement of 41 per cent., hardening began in $5\frac{1}{4}$ hours, and the time of setting was $8\frac{1}{2}$ hours.

Even more conclusive are results published by A. Hauenschild, who ascertained that the quantity of water the mortar required for mixing increased with the fineness, and the litre weight decreased strongly with increased fineness. Hauenschild traced the decrease in specific gravity to the absorption of water and carbon dioxide by the fine dust. Very few of the samples were quick-setting.

From results given in a table it is clear that the residue from the 5,000-mesh sieve has only very slight hydraulic properties. The object in the cement industry should therefore be to reduce the residue on the 5,000-mesh sieve to vanishing point, which is not impracticable, as Hauenschild's samples were ground in the most various mills. From the foregoing it is economically possible to produce a slow-setting cement of fineness far below that of the usual commercial cement, and that the alleged danger limit of 10 to 15 per cent. residue does not exist.

Cement ground fine in the laboratory is often quick-setting, while the cement on commercial scale remains slow-setting, which the author ascribes to the presence of too little moisture in the laboratory mill to slake the free lime to $Ca(OH)_2$. The difference certainly disappeared when the laboratory mill had more moisture. In the hot dry summers of America the author has also avoided quick-setting by copious employment of water.

FINE GRINDING OF PORTLAND CEMENT.—P. C. B. (*Tonind. Ztg.*, 41, 394, 1917). Reference is made to H. Kühl's article (p. 197), and some particulars are given concerning a clinker of the average composition: 20·9 silica, 9·6 R_2O_3, 67·1 lime, 1·0 magnesia, and 1·0 loss on ignition (total 99·6), with Hydr. modulus 2·15—2·20, silicate modulus 2·05—2·25, $Al_2O_3 : Fe_2O_3$ about 2·5, and ground to leave 3—7 per cent. on 4,900-mesh sieve. All tests with 2—3 per cent. raw gypsum gave decided quick-setting cements and variation of the gypsum addition as sprinkling of the clinker produced no result. The same clinker on a large scale, freshly ground, up to 5 per cent. on 4,900-mesh sieve gave a cement faultless in every respect, with a setting time of about 3 hours (beginning, but ending in 6 hours). For a trial the grinding was continued to give up to 2 per cent. on 4,900-mesh sieve, without materially affecting the setting time. Another instance is mentioned where a cement, without adding gypsum, was very slow-setting, but a laboratory ground specimen gave a decidedly quick-setting cement.

Some cements particularly rich in alumina are very sensitive to fine grinding.

INFLUENCE OF DILUTE SULPHATE SOLUTIONS ON THE CONSTANCY OF VOLUME OF CEMENTS.—H. Passow and M. Schönberg (*Tonind. Ztg.*, 41, 393, 402, 412, 420, 427, 435, 1917). A report of tests made with Portland cement, iron Portland cement, and blast furnace cement.

FINE GRINDING OF PORTLAND CEMENT.—J. Kreiten (*Tonind. Ztg.*, 41, 562, 1917). A further discussion of the subject.

CEMENT AS BY-PRODUCT.—A. Balster (*Tonind. Ztg.*, 41, 488, 1917). A brief discussion, with special reference to the production of cement from blast furnace slag, and in the manufacture of sulphuric acid by burning gypsum mixed with a proper amount of silicates.

BURNED GYPSUM.—E. C. (*Tonind. Ztg.*, 41, 605, 1917). A short discussion. Kiln plaster possesses advantages over boiled plaster, even if the two show the same water content. Pieces of gypsum up to 20 cms. in size are burned in kilns, after carefully removing ashes and carbon residues, whereas in boilers ground gypsum is dealt with. It is assumed that kiln plaster contains about a third each of plaster with 6, 8, and 10 per cent. water respectively.

TRIALS WITH BLAST FURNACE SLAGS.—(*Tonind. Ztg.*, 41, 661, 667, 673, 1917). The chemical composition is given for a number of samples, and the results of certain other tests.

ALTERATION OF THE TIME OF SETTING OF CEMENT.—E. S. (*Tonind. Ztg.*, 41, 696, 1917). A normal cement (which begins to harden not less than an hour after mixing with water), if kept for a time, alters sooner or later in its time of setting, and occasionally becomes almost suddenly a quick-setter. The time of setting of a cement depends on its composition, fineness of texture, temperature, and the quantity of water mixed with it, as well as the salts contained in the water.

Among these salts, calcium chloride lengthens the time of setting without injuriously affecting the cement, and it can therefore be used for prolonging the time of setting of quick-setting cements. A distinct effect is produced by only 1 per cent. of calcium chloride.

ACTION OF CANE SUGAR ON CEMENT.—G. B. (*Tonind. Ztg.*, 41, 727, 1917). A note on the curious action of sugar on cement, which had been put in old sugar bags.

PRODUCTION OF CEMENT WARES.—(*Tonind. Ztg.*, 41, 799, 822, 842, 1917). A discussion of the question whether it can be considered a trade.

TENSILE AND CRUSHING STRENGTH OF FERRO-CONCRETE.—B. Haas (*Tonind. Ztg.*, 41, 835, 847, 851, 1917) A general discussion.

CLASSIFICATION OF FURNACE SLAGS.—H. Lang (*Mining Press*, 116, 619, 1918). Slags have been classified in various ways: according to the predominant acid constituent into silicate slags, phosphate slags, aluminate slags, titanate slags, and fluoride slags; simply into acid or basic slags according to composition; into iron slags, copper slags, lead slags, etc.

In the metallurgical classification of silicates, natural and artificial, subsilicates contain two atoms of basic to one of acid oxygen, singulo-silicates one of basic to one of acid oxygen, bisilicates one of basic to two of acid oxygen, trisilicates one of basic to three of acid oxygen, quadri-silicates one of basic to four of acid oxygen, and sesqui-silicates two of basic to three of acid oxygen. It is considered that substances which crystallize are made up of acid and base in one or other of these proportions, and not of mixtures of two or more. Crystallization is confined mainly to the singulo- and bisilicates, neither the extremely acid nor the extremely basic compounds being found in nature.

The classification and discussion of slags are often attempted from the same standpoint, the slags being considered as a class analogous to simple silicates. The subject of slag constitution receives little help in this way, and even in the case of slags free from the disturbing influence of alumina, analyses commonly indicate that the ratio of basic oxygen to acid oxygen may be as 9 : 10, as 7 : 11, or as 4 : 8, etc., but rarely as 1 : 2, or as 2 : 3, which would conform to the conventional silicate types. Unwarranted conclusions may easily be drawn from analyses concerning the chemical nature of slags. The analyses are not exact enough to permit of close discrimination. The functions of several of the ordinary constituents of slag are not well enough understood, and further, the different bases do not often combine with the acid to form compounds of the same acidity in any given slag. Under conditions that will allow the different constituents to group themselves according to their preferences, as in the pyritic furnace, singulo-silicate of iron is formed, and bisilicate of lime This may be inferred from what seems to be fact, namely, that all the other heavy metals, whose action in several respects is analogous to that of iron, will likewise form singulo-silicates under similar circumstances, and magnesia and baryta will form bisilicates under the same circumstances. Pyritic slags containing a notable quantity of lime, together with ferrous oxide, would mostly be classed as sesqui-silicate slags when the analysis is exact enough to enable any reasonable conclusion to be drawn, but observation shows that they are made up of a mixture of singulo- and bisilicates. Thus the usual designation of slags by their degree of acidity is purely conventional, and has no certain relation to their internal constitution.

On the introduction of pyritic smelting a better inkling was obtained as to the composition of slags, considered with regard to the different silicates contained in them. In the pyritic furnace an ample amount of iron in the form of sulphides is always at hand, and it can make its escape either in the form of matte or of slag. Unsaturated silica meeting the fused sulphide decomposes it, giving rise to the singulo-silicate of iron, which is the main ingredient of such slags and sometimes almost the only one. The conclusion, based on the comparison of many analyses of pyritic slags, that the silicate molecule contains ferrous oxide and silica in the proportions $2FeO : SiO_2$, constitutes a notable advance in slag interpretation, especially as other facts point in the same direction. Given a pyritic slag containing only ferrous oxide and lime as bases, the degree of acidity of the lime silicate is easily ascertained to be the bisilicate, in which one molecule of lime is combined with one of silica.

In slags resulting from other processes the elements are rarely found in the precise proportions necessary to form normal, or what might be called "standard" silicates, which must conform to the law of multiple proportion. But slags, like native minerals, may be looked upon as containing a portion of standard compounds of recognised basicity mixed with substances in which the principle of chemical proportion does not exist. From a practical point of view the slight excesses or deficiencies in either base or acid are of little

consequence, for so long as a mineral is fusible it serves all the purposes of a favorable ore constituent in the charge. What is known about slags is almost entirely empirical, and the working limits of furnace slags are well known.

The remarkable solvent power of molten slags enables them not only to dissolve and mingle in an apparently homogeneous fluid, but also to absorb other bodies of the most unlike kinds. Silica, or lime or other base, in excess of the amount necessary to form any definite silicate, is readily taken up. The salts occurring in slags "may be regarded as silicates formed at the furnace temperatures, existing as definite chemical compounds under conditions dissimilar from those explained by the laws of definite proportion"; or "they may be considered as mixtures of definite silicates in solution, whatever that may be. It is probable that, just as glass is known to be a mixture of silicates existing as colloids, so the explanation of much that is found in slag-making must be sought in the principles of colloid chemistry. From a practical point of view it makes little difference which side prevails."

In pyritic smelting, and there only, the slag-formers have an opportunity to assert their preferences, and there is evidence of a strong tendency to assume the simple relations demanded by chemical theory. In every other case the slag-formers are grouped by force, as it were, that is, they are compelled to combine by the powerful agency of heat. Even in the case of pyritic works, a few of the slags seem to contain excesses or deficiencies of components, for which there is no present explanation unless it may lie in the appearance of the silica as free quartz, a not uncommon thing in any form of smelting. In one plant the author noticed the constant discharge of unmelted grains of quartz in a slag that, when separated from them, was found to contain the proportions conformable to theory. Where analyses show deficiencies of silica in pyritic slags, this might have been caused by the presence of large amounts of magnetite, which is found in many slags, and is a frequent product of pyritic work. Whole series of analyses have proved to be unreliable through disregard of simple precautions; small residues of silver, sulphate of lead, and sulphate of baryta, vitiate many an otherwise unexceptional estimation of silica, and it may be that some of the excesses of that substance in slag reports are due to this cause.

WHITE CEMENT.—W. C. Ewing, U.S. Pat. 1,239,579, Sept. 11th, 1917. A white cement is produced by mixing 20 parts of ordinary Portland cement and 1 part each of diatomaceous earth and slaked lime.

WHITE PORTLAND CEMENT.—A. Heilbronner, U.S. Pat. 1,239,912, Sept. 11th, 1917. This is made by heating ordinary ferruginous raw cement-forming materials gradually up to 1,400°—1,500° with calcium chloride, accompanied by a blast of air and superheated steam. In this way metallic chlorides are volatilized, particularly ferric chloride.

VERY STRONG WATERPROOF CEMENT.—W. Giese, Ger. Pat. 293,715, March 16th, 1915. During the grinding of ordinary cement clinker are added small proportions of liquid sodium or potassium silicate and of a suitable calcium compound (preferably the chloride or carbonate, the latter being used in the form of limestone, chalk, dolomite, etc.). During the setting of the cement the alkaline silicate reacts with the constituents of the cement, forming a mass of calcium metasilicate or orthosilicate which is not easily permeable by water. The calcium compound added counteracts the effect of the alkaline silicate in reducing the resistance to pressure and fracture. With addition of 2·5 per cent. of alkaline silicate, and the same percentage of calcium chloride or carbonate, the permeability of cement is reduced to one-tenth that of the plain cement, and its strength is also increased.

PLASTER COMPOSITION.—C. Noll, U.S. Pat. 1,239,032, Sept. 4th, 1917. A plaster is formed from a mixture of 15 parts slaked lime, 20 yellow clay, 60 silica sand, and 5 parts rye flour.

HYDRATING LIME.—W. E. Carson, U.S. Pat. 1,239,256, Sept. 4th, 1917. Two lots of lime, one containing more magnesia than the other, are slaked separately, and the dry hydrated powders so obtained are mixed together. The product is a dry dustless hydrated lime of high plasticity.

ALKALIES FROM CEMENT-KILN DUST.—S. B. Newberry, U.S. Pat. 1,239,616, Sept. 11th, 1917. Cement-kiln dust is moulded into small blocks which are charged into a vertical kiln with a blast of air under pressure (5 to 20 lb. per sq. in.). On cooling the gases thus produced alkalies are condensed.

CEMENTS.—Chance and Hunt (*Pat. J.*, No. 1,507, 1917). Pat. No. 110,258, Jan. 20th, 1917. An acid-resisting cement consists of acid-resisting siliceous material, a solution of silicate, and not more than 5 per cent. of plaster of Paris or calcium sulphate, or a mixture of materials forming calcium sulphate. An example is given consisting of 8 parts by weight ground stoneware, 7 parts Leighton sand, 2 parts ground blue brick, 3 parts sodium silicate solution (60° Tw.), and 0·12 part plaster. Finished work made from cement is heated at 100° C. for several days, or at a higher temperature for a shorter time. The product is suitable for acid storage tanks, towers, and chimneys.

POTASSIUM SALTS AND CEMENTS.—F. W. Huber and F. F. Reath (*Pat. J.*, No. 1,509, 1917). Pat. No. 110,540, Sept. 26th, 1916. The fine dust from an ordinary cement roast, or from one in which minerals such as felspar have been employed is mixed with an alkaline-earth fluoride such as fluorspar and with such other materials as are necessary to make up its composition to that of a normal cement roast, and the charge is roasted in the usual manner to obtain a cement clinker, the dust being collected. The dust is digested with water and an alkaline-earth compound such as calcium sulphate to regenerate the alkaline-earth fluoride, leaving soluble alkali salts in solution.

POTASSIUM SALTS.—F. W. Huber and F. F. Reath (*Pat. J.*, No. 1,516, 1918). Pat. No. 111,845, Nov. 14th, 1917. Potassiferous flue dust such as that obtained by electric separation from the flue gases of cement kilns is treated with water and the solution separated from the insoluble residue, all the operations being effected at a temperature not lower than about 85° C., preferably nearer 100° C., so as to avoid the formation of the insoluble double salt $CaSO_4.K_2SO_4.H_2O$.

POTASSIUM CHLORIDE.—British Cyanides Co., K. M. Chance, etc. (*Pat. J.*, No. 1,519, 1918). Pat. No. 112,338, Feb. 8th, 1917. Potassium chloride is recovered from the materials charged into a blast furnace by adding to the charge sodium chloride or an alkaline earth chloride and separating the dust from the gases. Specification 2,134/71 is referred to.

ALKALINE SALTS AND ALUMINA.—A Christiania Firm (*Pat. J.*, No. 1,523, 1918). Pat. No. 112,948, Jan. 24th, 1918. Plagioclase rocks [with soda and lime felspars] are treated with dilute or concentrated mineral acids to obtain solutions from which alumina containing little iron can be precipitated, leaving salts of alkalies and of alkaline earths in solution. Constituents such as anorthite and labradorite dissolve, while ferruginous constituents such as hypersthene, diallage, almandine, and epidote remain unattacked.

POTASSIUM CHLORIDE.—E. A. Ashcroft (*Pat. J.*, No. 1,525, 1918). Pat. No. 113,211, June 5th, 1917. Potassium chloride is obtained from silicates such as felspar, leucite, etc., by treatment of the crushed material with fused sodium chloride or alkaline earth chloride, in closed crucibles or retorts, or by causing the fused salt to percolate through the crushed silicate.

ALKALINE NITRATES AND ALUMINA.—H. Goldschmidt (*Pat. J.*, No. 1,525, 1918). Pat. No. 113,276, Feb. 4th, 1918. Alumina is obtained from materials containing compounds of other metals (sodium, potassium,

calcium, magnesium, by converting all the metals into nitrates and heating the mixture to about 140—300° C.—if desired under reduced pressure so as to decompose only the aluminium nitrate. The undecomposed nitrates are removed by lixiviation and may be separated or used as a manure, and the nitrogen oxides evolved may be converted into nitric acid. The process may be applied to plagioclase rocks, which are treated with nitric acid as described in Specification 112,948.

ALUMINA, etc.—A Christiania Firm (*Pat. J.*, No. 1,525, 1918). Pat. No. 113,278, Feb. 5th, 1918. Plagioclase rocks are heated with "acid gases or vapours," chlorine, hydrochloric acid, and nitrogen oxides being mentioned.

PORTLAND CEMENT.—N. S. Borch (*Pat. J.*, No. 1,528, 1918). Pat. No. 113,785, Feb. 19th, 1918. Portland cement is made from a raw mixture which contains a proportion of raw materials having hydraulic properties, such as a mixture of slag and lime, by adding to the slurry a substance which prevents or delays the setting of the slurry, for instance ¼ per cent. (calculated with reference to dry slag) of cane sugar, oxy-acid, oxy-aldehyde, or oxy-ketone.

POTASH FELSPAR; SILICATES; CEMENTS, etc.—E. A. Ashcroft (*Pat. J.*, No. 1,534, 1918). Pat. No. 114,743, July 20th, 1917. Soda present in association with potash in natural or artificial silicates or aluminates, such as felspar or the materials mentioned in Specification 113,211 (including leucite, etc.), is replaced by potash by heating the material with an excess of potassium salt such as the chloride, sulphate, or nitrate, and then washing out the soluble salts. The product, such as potash felspar free from soda which is suitable for ceramic purposes, may be treated at a suitable temperature and pressure with lime or magnesia or both, and water or steam, the result being a pure solution of caustic potash and a residue suitable for the production of cement. When a sodium silicate or aluminate is used to react with potassium chloride, an insoluble silicate or aluminate remains.

SLAG CEMENTS.—A. A. Deckers (*Pat. J.*, No. 1,534, 1918). Pat. No. 114,794, Dec. 11th, 1917. Slag cement is made by grinding granulated slag under water, mechanically drying (for instance, by centrifugal means) the ground slag until its water content is reduced to 4·7 per cent., mixing with ground quicklime in the required proportions and finally grinding the mixture.

SHAFT KILNS.—J. P. Scheffers and M. A. Van Roggen (*Pat. J.*, No. 1,536, 1918). A gas-fired kiln for burning lime, cement, etc., comprising an upper part of inverted pyramidal form, and a lower (and narrower) burning and cooling part of uniform rectangular cross-section.

CEMENTS, BRICKS, etc.—H. W. Charlton, (*Pat. J.*, No. 1,540, 1918). Pat. No. 115,946, June 27th, 1917. Alkaline and other silicates are digested in water with lime, part of the alkali (if present) passing into solution and being capable of recovery, while the insoluble residue is dried and forms a cementing-material containing water of combination. According to an example, 30 to 60 parts felspar are digested with 60 to 30 parts lime, in 300 to 500 parts water at a pressure of about 200 lb. per sq. in. at 160—200° C. for 2 to 4 hours. The cementing-material may be mixed with sand or other rock material, moulded, and steamed to form bricks, artificial stone, electric insulators, etc.

POTASSIUM SALTS.—A. D. Hone (*Pat. J.*, No. 1,540, 1918). Pat. No. 116,118, May 9th, 1917. Potassium salts are obtained by treating a siliceous rock or earth with a solid fluorine compound and an acid, such as sulphuric acid, to liberate nascent hydrofluoric acid in such quantity as to remove the silicon as fluoride. The silicon fluoride is converted into a fluosilicate, which may be used as the fluorine compound for treating more rock material. Specifications 5,559/02 and 23,473/04 are referred to.

POTASSIUM CHLORIDE.—E. E. Dutt and P. C. Dutt (*Pat. J.*, No. 1,542, 1918). Pat. No. 116,438, Oct. 16th, 1917. Potassium chloride is obtained from felspar by heating the powdered substance to a temperature of 700° to 900° C. in a retort into which is passed the vapour of arsenic trichloride. A mixture of potassium chloride, aluminium silicate, and silica is left in the retort and arsenic trioxide distils off. The residue is lixiviated, and the solution of potassium chloride evaporated. When iron oxide is present in the felspar in quantity calcium hydrate is added to precipitate the iron salts as hydrate.

HYDRAULIC CEMENT AND ALKALI MANUFACTURE.—A Swedish Firm (*Pat. J.*, No. 1,547, 1918). Pat. No. 117,460, July 11th, 1918. In the manufacture of cement and alkali from felspar or other alkaliferous silicate minerals and lime or substances containing lime, the mixture is first heated by means of fuel to such a temperature that the carbonic oxide is driven off and the calcined mixture is then introduced into an electric furnace in which the heating is continued until cement is formed and the alkali driven off as vapour which is condensed and collected. The first heating may be conducted in a rotary furnace up to 900° C., and the second heating in an electrical resistance or radiating furnace up to 1,400° C. or higher. A suitable electric resistance furnace is briefly described, as also are arrangements for condensation of the alkali.

CALCIUM SULPHATE; PLASTER OF PARIS COMPOSITIONS.—F. Hartner (*Pat. J.*, No. 1,548, 1918). Pat. No. 117,605, May 17th, 1918. Anhydrite is ground with alkaline materials such as oxides or hydrates of alkalies or alkaline earths, or with materials containing lime such as cements, slags, and waste lime or mortar, the addition of a small quantity of which is sufficient, causing the anhydrite to set like burnt plaster of Paris. Inert or filling materials may be added.

POTASSIUM CARBONATE.—S. R. Scholes (*Pat. J.*, No. 1,549, 1918). Pat. No. 117,755, Nov. 5th, 1917. Minerals such as felspar are ground and mixed with a sodium or potassium compound (such as the carbonate) in quantity such as to supply one equivalent of alkali metal oxide to each two equivalents of silica in the mineral, and the mixture is fused. The melt is poured into water and ground, and is then boiled with water and treated with carbonic acid or gases rich in carbonic acid, for instance cement kiln gases containing potash. The alkali carbonates are then formed in solution, leaving hydrated silica, alumina, etc., as a precipitate. The solution is filtered off and evaporated; a quantity equal to that extracted from the rock is withdrawn and the remainder is used to treat the next batch of rock.

POTASSIUM SALTS.—F. Tschirner (*Pat. J.*, No. 1,550, 1918). Pat. No. 117,870, Nov. 2nd, 1917. Potassium chloride is obtained from glauconite (greensand marl) or the like by heating to 800—820° C. a mixture of the mineral with "lime sand" (grey calcareous marl), chalk, marble, common marl, calcium carbonate sludge or corresponding compounds of magnesium, barium, or other alkalies or alkaline earths, and with calcium, sodium, or other chloride, or in presence of hydrochloric acid gas; or the mineral may be heated first with the alkaline reagent and then with the chloride, or vice versa; or the mineral may be heated with a mixture of slaked lime and bleaching powder. Alternatively, the chloride reagent may be omitted, the other minerals being first heated to 600° C. and then ground in water and treated with chlorine, dried, and finally heated to 800—820° C. The product is leached to obtain potassium chloride, which is separated from the other soluble materials in known manner.

POTASSIUM SALTS.—Stafford Coal & Iron Co. and J. R. Richmond (*Pat. J.*, No. 1,550, 1918.) Pat. No. 117,991, Sept. 8th, 1917. Blast furnace dust is dissolved in water and treated with air to render the iron compounds insoluble.

Lime or the like is then added to precipitate magnesia, and the solution is then evaporated to dryness and calcined, the residue being finally redissolved and evaporated to obtain crystals. Ammonium chloride may be obtained by giving the dust a preliminary heating, or ammonia may be recovered when the lime is added. Apparatus is illustrated.

POTASSIUM CHLORIDE.—E. A. Ashcroft (*Pat. J.*, No. 1,558, 1918). Pat. No. 119,492, Aug. 28th, 1917. Potassium chloride is obtained from potash-bearing minerals such as felspar, mica, alunite, or leucite, or from cement-kiln dust, blast furnace dust, wood or plant ashes, beet-sugar residues, etc., by treating the substances with chlorine gas while suspended in a fused bath of sodium or potassium chloride, or a mixture. A chlorine carrier such as a salt of iron, manganese or chromium, and a reducing agent such as carbon or sodium, potassium, zinc, lead, or iron sulphide may be added. The reaction is carried out in a converter at about 800—1,100° C., and may be continued until some constituents are separated by volatilization. Potassium chloride is separated by lixiviation.

THE CONTENT OF SOILS IN AMORPHOUS SILICA.—B. von Horváth *Zentralblatt f. Agrikulturchemie*, 47, 97, 1918; abstracted from *Internationale Mitteilungen für Bodenkunde* 1916, Bd. VI, p. 288) The quantity of amorphous silica contained in soils has been little known hitherto. Piedzicki (*Mitteilungen des landwirtschaftlichen Instituts der Universität, Leipzig*, 1901, 2, pp. 1—51), has assumed for the amorphous silica of soils the quantity dissolved in 90 minutes in 10 per cent. NaOH-lye on the water-bath. But the values thus obtained seem for obvious reasons much too high; thus according to investigations of the author a 10 per cent. NaOH-lye dissolves of 0·5 mm. and still smaller granules of natural quartz 0·29 per cent., of felspar 1·40 per cent., and of sodium silicate 55·0 per cent.

The author thinks that if it be even possible that the results of experiments performed with such strong solvent maintain characteristic values with different types of soil, they nevertheless cannot be regarded as measuring the amorphous silica contained in the soil. For from the amount of the original amorphous silica and that dissolved from compounds containing silica—that is, from two irregularly varying quantities of silica—cannot even be determined the relative value of the amorphous silica. The solvent must thus be much weaker than 10 per cent. NaOH-lye, and must be chosen such that it dissolves completely the amorphous silica of the soil without attacking the other compounds containing silica. Such appears to the author to be yielded when it dissolves considerably more of an artificial amorphous silica than a soil contains of amorphous silica. For in case it completely dissolves the amorphous silica of the soil, and if moreover it does not attack silicates and quartz, it is thus suitable as solvent of the amorphous silica of the soil.

According to determinations of the author a 1 per cent. Na_2CO_3 solution, after 15 minutes action at 100° C., dissolves the amorphous silica in two types of soil containing respectively 5 and 4 mg., and completely, because under like conditions a quantity respectively 48 or 60 times as great of pure amorphous precipitated silica was dissolved (0·22 g.). For if more than 5 or 4 mg. respectively of amorphous silica had been present in the two types of soil, the author concludes that the 1 per cent. Na_2CO_3-solution must have dissolved out of these also 0·22 g. silica. It further resulted that under the same conditions the quantity of dissolved silica from 0·5 mm. size and still smaller granules of quartz sand amounted to about 0·006 per cent., and with 1 mm. size and still smaller granules of felspar to 0·01 per cent. Accordingly the author holds the 1 per cent. solution to be suitable at least for relative determinations of the amorphous silica of the soil and recommends that 100 cc. of the solution be allowed to act for 15 minutes at 100° on 5 g. of soil.

The numbers obtained by this method for the quantity of amorphous silica present in the soil show very small values. But this stands in complete harmony with the views of E. Ramann. That the amorphous silica in spite

of the perpetual weathering is present in the soil only in very small quantities, the author explains, is because in the weathering is formed simultaneously with the silica alkali carbonate, which acts on the amorphous silica with formation of K_2SiO_3, and this is equally carried off as a compound well soluble in water. Even to the amorphous silica remaining unaltered, fairly soluble in water, the same fate should fall.

XII.—ANALYTICAL PROCESSES.

THE RATIONAL METHOD OF CLAY ANALYSIS.—J. C. Thomlinson (*Chem. News*, 116, 245, 1917). To adapt this for an estimation of the quartz and felspar constituents as well as true clay, 5 grms. of air dry clay are heated with successive portions of sulphuric acid (1 : 3) for an hour or two on the water bath, taken down until the acid fumes on a sand-bath, and after dilution with water the contents are decanted through a filter, reserving the residue, which is treated once or twice with solution of caustic soda 1 per cent. and sodium carbonate crystals 10 per cent. in solution, again decanting, and finally washing on to a filter with dilute hydrochloric acid. The silica and quartz residue after the contents and filter have been dried, ignited, and weighed are treated similarly. The estimation of true clay by difference is achievable, and its analysis useful. The analysis of the quartz and felspar as well as of the decanted solution is especially valuable, as the potash should be estimated in both.

NEW MICROCHEMICAL REACTION FOR CALCITE.—St. J. Thugutt (*Zeits. Kryst. Min.*, 54, 197, 1914; from *Sitzungsber. Warschauer. Ges. Wiss.*, p. 38, 1911). Calcite intermixed with zeolites can be recognised by the following reaction. The powdered mineral (with grains about 0·1 mm. diam.) is heated on platinum foil over a Teclu burner for 15 seconds, and then treated with decinormal cobalt nitrate solution. Calcite acquires a thin coating of a blue basic cobalt salt, whilst zeolites remain unaffected. On removing excess of the cobalt solution and adding decinormal silver nitrate solution, the bases of the zeolites are soon replaced by silver (detected with potassium chromate), whilst the basic cobalt salt blackens owing to the formation of $CO(OH)_3$, which quickly reduces the silver salt, forming a deposit of silver on the calcite.

XIII.—INSTITUTES, EDUCATIONAL, HISTORICAL.

THE EARTHENWARE FACTORY AT TIEFENFURT.—K. Strausz (*Deut. Töpf.-Zieg.-Ztg.*, 48, 85, 1917). A brief description of the decorations (mostly printed) on several plates.

POTTERY IN BRANDENBURG.—K. Strausz (*Deut. Töpf.-Zieg.-Ztg.*, 48, 190, 1917). Extracts from old documents, dated 1735, relating to potworks in Brandenburg on both sides of the Oder and Elbe, but especially in Berlin.

OLD NAUMBURG POTTERY.—K. Strauss (*Tonind. Ztg.*, 41, 211, 1917). A historical account (with illustrations) of the progress of the potter's art at Naumburg in Western Silesia. The first pottery here dates back to 1547. Much of the ware made is brown, but some is white.

OLD MOSCOW STONEWARE.—K. Strauss (*Tonind. Ztg.*, 41, 259, 1917). A historical account (with illustrations) of Moscow pottery, which dates from some time before 1654, the date of the earliest known potter's seal.

OLD BUNZLAU ART POTTERY.—K. Strauss (*Tonind. Ztg.*, 41, 643, 1917). A historical account, with illustrations.

THE OPPENHEIM COLLECTION OF STONEWARE.—J. Gr. (*Tonind. Ztg.*, 41, 803, 1917). A notice of a published illustrated catalogue.

HUNGARIAN PORCELAIN FACTORIES.—A. Kohut (*Ker. Rund.*, 25, 59, 1917). A notice, mainly historical, of the factories in Hungary for making china and other claywares (including the productions of Zsolnay).

CERAMICS OF PRIMITIVE RACES.—W. Hacker (*Ker. Rund.*, 25, 249, 256, 1917). A brief general discussion of the condition of pottery among people in a low state of civilization, such as Indians, Aborigines of New Guinea, German East Africa, Peru, Mexico, Fiji Islands, etc.

FAYENCE FACTORY AT FRANKFURT AN DER ODER.—K. Strausz (*Deut. Töpf.-Zieg.-Ztg.*, 48, 75, 1917). Some particulars concerning the establishment of this factory in the eighteenth century, by Karl Heinrich, as well as several others. Nothing appears to be known now of the products of the factory.

EXTRACTS FROM DOCUMENTARY RECORDS AT FRANKFURT A/O. —K. Strausz (*Deut. Töpf.-Zieg.-Ztg.*, 48, 182, 1917). Has reference to "Royal and native porcelain and fayence manufactures of prohibited importation in the like foreign wares and particularly English earthenware, 1753." Also includes extracts dated 1766, 1771, and 1780. Several other factories are mentioned, besides those of Frankfurt an der Oder.

Review.

Die Arbeitsmethoden der Silikatchemie.

By Reinhold Reike. Braunschweig, 1917.

As the title indicates, this book deals with the methods used in the investigation of the silicates. The first part describes the various ways in which silicates may be formed, including "dry" and hydrothermal synthesis, reactions in the solid state and those involving the use of gases and vapours. This is followed by one section on the isolation of the compounds by mechanical and chemical means, and by another giving an account of the analytical processes, with special reference to silica and water determinations. The fourth section, which occupies two-thirds of the book, is concerned with the investigation of silicates by means of physical chemical methods. Although the descriptions are brief this part is very comprehensive and includes the determination of the physical properties of the crystalline solids, the molten substances and glasses. Naturally much of the space is devoted to a discussion of the methods and apparatus for melting point determinations. The final chapter deals with the constitution of the silicates.

Although the descriptions are much too brief to be of any value to those working on the subject the book may be said to fulfil the purpose for which it is written, that is, to give to those who are not specialists in this branch, some idea of what has been done. In order to compensate for the lack of detail, a short bibliography of the more important papers is given at the end.

A.S.

Abstracts.

I.—RAW MATERIALS.

POTASH FROM FELSPAR.—D. J. Benham (*Chem. Trade J.*, **61**, 220, 1917). Abstracted from the *Canadian Chemical Journal*. Description of a process invented by A. Gravel, and used by the National Potash Corporation of Toronto, for extracting potash from felspar. It consists in heating to a high temperature in a blast furnace 110 tons of a mixture of felspar, coal, calcium chloride, and limestone, the limestone being used to render the slag fluid. Potassium chloride distils over and meets a current of steam in a condenser; the solution is evaporated and the salt crystallized out in a high state of purity. Under the most favourable conditions over 90 per cent. of the potash in the felspar was obtained; the percentage of K_2O in the felspar ranges from 8 to 14. Improvements in the collection of the vapours are in progress. A satisfactory process for dealing with the soda vapours has also been developed. The mother liquor containing the potassium salts, after being drawn off from the condensing and filtering equipment, is subjected to centrifugal treatment and evaporation.

It is stated that it is possible to adapt the process and the equipment so as to use cement marl as a raw material instead of felspar (where latter not readily obtainable). It is also possible to utilise either rotary kilns or blast furnaces of a certain type for releasing the potassium fumes. The slag from the blast furnace operations is made into sewer-pipes, tiles, and paving bricks, by pouring it direct from the furnace into moulds. It has a peculiar porcelain-like surface like all felspar products.

All the potash of the felspar does not volatilise at the same temperature, some passing off at about 900° C., more at 1,000° C., and so on, the last portion being driven off at about 1,600° C.

POTASSIUM AND ALUMINIUM SALTS FROM MINERAL SILICATES.—J. C. W. Frazer, W. W. Holland, and E. Miller (*Chem. Trade. J.*, **61**, 363, 1917). A paper read at a meeting of the American Institute of Chemical Engineers.

Many patents have been obtained for processes in which felspar is treated to recover potassium and aluminium compounds, but most of them use very high temperatures, and they often depend on the separation of potash by volatilization. Such processes are not only expensive, but it is difficult to separate the potash from the other constituents after the silicate has been decomposed.

The authors, in order to avoid excessive expense, did not attempt to decompose the felspar completely, but to transform it by successive stages into products analogous to certain well-defined natural minerals. Most of the available potash in soil results from weathering of felspar. The final product of this slow weathering product is kaolinite, $H_4Al_2Si_2O_9$. Certain minerals, such as leucite, have a composition intermediate between felspar and kaolinite, though in all probability they are not formed during the weathering process. A point of great importance is that, unlike felspar, leucite is easily decomposed by mineral acids, silica being set free and salts of potassium and aluminium formed. It was soon ascertained that by treating felspar with a strong alkali, a substance analogous to leucite is obtained, and this product possesses the convenient property of fractional decomposition when treated with dilute mineral acids.

The authors mix intimately finely-ground felspar (about 50 mesh) with about 0·8 of its weight of potassium hydroxide (or an equivalent amount of

sodium hydroxide) dissolved in a small quantity of water. The mixture is heated in an open iron vessel until the water has evaporated, and afterwards for about an hour at 275° to 300° C., the reaction taking place in the latter stage, forming alkali silicate and a new silicate containing two-thirds of the original silica. The new silicate when dried has approximately the composition of leucite: $KAlSi_3O_8 + 2KOH = KAlSi_2O_6 + H_2O + K_2SiO_3$.

The new silicate or "artificial leucite" is insoluble in water, and so may be separated from the soluble alkali silicate and excess of alkali. The liquid containing the two latter, on treatment with lime, and filtering from the insoluble calcium silicate formed, yields on evaporation caustic alkali, which is used for another quantity of felspar. There is no loss of alkali, apart from unavoidable mechanical losses. The artificial leucite contains all the potash and alumina and two-thirds of the silica of the original felspar. It is mixed with water and dilute hydrochloric acid is added slowly with constant stirring to avoid local excess of acid (which would tend to dissolve some of the aluminium). The insoluble aluminium silicate is separated by filtering off the potassium chloride solution, and is somewhat analogous to kaolinite. By treating with sulphuric acid (not too dilute) aluminium sulphate is formed and gelatinous silica is precipitated. Evaporation is carried on to dryness in order to render the silica insoluble, and the aluminium sulphate is then dissolved in water and separated by filtration from the silica. The same product is obtained by the action of sulphuric acid or certain other silicates, such as sericite and clay.

Sulphuric acid or nitric acid (instead of hydrochloric acid) may be used if desired to obtain potassium sulphate or nitrate instead of the chloride.

The yield of potassium chloride by this method on a laboratory scale is practically theoretical, and of aluminium sulphate about 86 per cent. of the theoretical, the actual weight of the latter being about four times that of the former. Under normal conditions the process would be essentially an aluminium sulphate process with potash as a by-product, and the value of the process will accordingly depend largely on the cost of producing aluminium sulphate free from iron as compared with the cost by the present method in which bauxite is used.

POTTERY CLAYS IN MALAY STATES.—(*Pot. Gaz.*, **42**, 68, 1917). A report on the occurrence of various kinds of clays, including supposed kaolins.

THE CLAYS AND MARLS OF NORTH STAFFORDSHIRE.—J. T. Stobbs (*Pot. Gaz.*, **42**, 155, 1917). See also TRANS., **16**, 107, 1917.

THE CLAYS OF SOUTH STAFFORDSHIRE AND ITS BORDERS.—W. S. Boulton (*Pot. Gaz.*, **42**, 595, 1917). See TRANS., **16**, 237, 1917.

BORAX AND BORIC ACID UNDER THE MICROSCOPE.—(*Pot. Gaz.*, **42**, 887, 1917). A descriptive article, with illustrations of crystals, etc.

BLUE AND BLACK BALL CLAYS UNDER THE MICROSCOPE.—(*Pot. Gaz.*, **42**, 892, 1917). A descriptive article with several illustrations.

FIRECLAYS AND GANISTERS OF THE SOUTH OF SCOTLAND.—L. W. Hinxman and M. Macgregor (*Pot. Gaz.*, **42**, 1,070, 1917). See also TRANS., **17**, 35, 1918.

MINERALS AT CONTACT OF GRANITE AND METAMORPHIC QUARTZITES.—A. Lacroix (*Bull. Soc. franc. de Mineralogie*, **41**, 16, 1918). Relates to the occurrence of certain minerals at Chizenil (Saône-et-Loire). *Pyrophyllite* constitutes laminæ often grouping into rosettes; it is readily distinguished from the muscovite (white mica) of the neighbouring quartzites by its pearly lustre and its want of elasticity; under the microscope, its high birefringence is accompanied by a value of the axial angle much greater than for muscovite. *Kaolinite* possesses the optical properties usual in this mineral; it forms glittering white hexagonal lamellæ, especially distinct when they

constitute concentrations; the kaolin exists sometimes with its own individuality, more frequently under the form of pseudomorph of andalusite or exceptionally of felspar. *Andalusite* presents itself under an unusual aspect, in large colourless or milk-white rods several millimetres in length, or in more or less granoblastic masses attaining the size of the fist and enclosing only a little rutile and sulphides; finally kaolinite epigenises it in part; andalusite then takes a very characteristic unpolished aspect. Microscopic examination shows that andalusite is one of the last minerals formed, for it encloses poikilitically corundum, diaspore, etc. All the optical properties are those of normal andalusite; yet the cleavage could not be detected. Analysis of a specimen not thoroughly purified gave 32·45 silica and 64·20 alumina. An exceptional specimen consisted of oligoclase-albite (partly transformed into kaolinite) and prisms of andalusite several millimetres in length completely transformed into *muscovite*.

POTASH FROM FELSPAR.—E. A. Ashcroft (*J. Soc. Chem. Ind.*, **37**, 10R, 1918). Report of paper on "A Neglected Chemical Reaction and an Available Source of Potash," read at a meeting of the Institution of Mining and Metallurgy. The reaction is that between finely crushed potash felspar and common salt at 900°—1,000° C., without access of air and moisture. The products are insoluble soda felspar (albite) and a mixture of potassium and sodium chlorides. The reaction is reversible, but by heating equal weights of felspar and salt for two hours at 1,000° C., 86 per cent. of the total potash can be readily extracted. It was estimated that with an emergency plant described 50 tons of 80 per cent. potassium chloride could be produced daily at an estimated all-in cost of £15—£20 per ton, but not more than £7 per ton in normal times. In the course of discussion P. G. H. Boswell pointed out that soda or soda lime felspars are in demand for glass-making (to supply alumina), and are particularly suitable for resistance glass, thermometers, and strong-necked bottles.

POTASH PRODUCTION IN GREAT BRITAIN.—(*J. Soc. Chem. Ind.*, **37**, 313R, 1918). A discussion of the possibilities as regards available sources, chiefly with reference to the flue dust and gases of blast furnaces, cement kilns and coke ovens.

POTASH FROM BLAST FURNACE DUST.—R. A. Berry and D. N. McArthur (*J. Soc. Chem. Ind.*, **37**, 1T, 1918). A general review of the question, with tabulated details respecting flue dusts, stove dusts, tube cleanings, spent liquor, etc. Also a bibliography. On p. 128 Mr. E. H. Lewis supplies some additional data.

POTASH INDUSTRY.—K. M. Chance (*J. Soc. Chem. Ind.*, **37**, 222T, 1918). A discussion of the prospects of establishing a potash industry in this country.

THE ALSACE POTASH DEPOSITS.—P. Kestner (*J. Soc. Chem. Ind.*, **37**, 291T, 1918). A general account of these deposits, with references to the other important deposits of Germany, Galicia, Spain, the United States, Italy, Tunis, Chile, and elsewhere; several of these are not strictly mine deposits but salt lakes (U.S. and Tunis).

KAOLIN IN QUEBEC.—J. Keele (*J. Amer. Cer. Soc.*, **1**, 8, 1918). An illustrated account of the only workable kaolin deposits in Canada. (See also Canadian Kaolin Products, TRANS., **17**, Abs. 63, 1918). Most of the washed china clay—representing about 40 per cent. of the crude product—is supplied to the paper trade. The washed china clay has a softening point at cone 34, and consists of 46·13 per cent. silica, 39·45 alumina, 1 per cent. total fluxes, the rest being combined water. The adjoining quartzite when crushed and washed contained 99·25 per cent. silica, 0·06 alumina, and 0·69 iron oxide.

FIRECLAYS IN NORTHERN IDAHO.—E. K. Soper (*J. Amer. Cer. Soc.*, **1**, 94, 1918). A brief account of the geological occurrence and extent of the clay deposits. The clay is said to be well suited for making firebricks.

THE CLAYS OF FLORIDA.—E. H. Sellards (*J. Amer. Cer. Soc.*, **1**, 313, 1918). Particulars as to properties and behaviour of samples of common clays, and also of the Florida plastic kaolin.

HIGH GRADE AMERICAN CLAYS.—H. Ries (*J. Amer. Cer. Soc.*, **1**, 446, 1918). An illustrated descriptive account of the occurrence and possibilities of further development of white clays, refractory bond clays, ball clays, saggar clays, flint clays.

PARTIAL PURIFICATION OF ZIRCONIA.—A. J. Phillips (*J. Amer. Cer. Soc.*, **1**, 791, 1918). An account of attempts to remove iron oxide, but leaving silica, alumina and titanium oxide. Eventually it was found practicable to remove nearly all the iron as chloride by means of a current of chlorine (first passed through water in a bubble tube) acting on a heated mixture of the crude zirconia and about 4 per cent. of finely powdered petroleum coke. Hydrochloric acid gas is formed, among other things, and as iron oxide mixed with carbon is volatilized as chloride in a current of hydrochloric gas, while zirconia is not affected thus, the latter remains and the iron is removed. The last 0·5 per cent. of iron oxide would not be removed by hydrochloric acid gas, but the more energetic chlorine effects its removal.

The treatment is applicable not only to the purification from iron of crude zirconia, but also to bauxite and flint.

CLAYS OF CANADA.—(*Sprech.*, **51**, 7, 1918). An article based on paper by H. Ries, *Bull. Amer. Inst. Mining Eng.*, p. 429, 1913, and *Trans. Amer. Cer. Soc.*, **14**, 82, 1912, also J. Keele, p. 152. It relates to fireclays as well as ordinary brick clays.

CHEMICAL CONTROL OF RAW MATERIALS.—L. Springer (*Sprech.*, **51**, 63, 68, 1918). A description of simple methods for conducting various important tests, including determination of moisture or water control in substances like soda, potash, Glauber salt, borax, saltpetre, of insoluble residue in fluxes, lime, manganese, etc., of lime in clay, etc., of composition of clays by elutriation and rational analysis, comparative iron content, of chlorides and sulphates in soda, potash, Glauber salt, etc.; also determination of soda and potash content, iron in all raw materials, and valuation of manganese. These apply not only to ceramic and clay industries but also to glass.

POTASH AS BY-PRODUCT OF CEMENT INDUSTRY.—W. H. Ross and A. R. Merz (*J. Ind. Eng. Chem.*, **9**, 1,035, 1917). The flue dust from cement kilns can be treated like silicate rocks for recovery of potash—(see *J. Ind. Eng. Chem.*, **9**, 467, 1917) (also Trans., **16**, Abs., 122, 1917). The flue dust, when fresh, consists of sulphates, chlorides, and sulphides (these especially in kilns fired by gas or oil) of potassium, sodium, and calcium, with some free lime. Analyses of the raw mixtures and the cement from 113 American works indicated 0·35 to 5·34 lb. of potash volatilized per barrel of cement, the average of 99 plants (excluding those using blast furnace slags) being 2·09 lb., or about 87,000 tons of K_2O annually. By the Cottrell process of electrical precipitation, 90 per cent. of the potash is recoverable (99 per cent. of the flue dust, but the remaining 1 per cent. is very rich in potash), or about 78,000 tons annually, assuming all the potash in the flue dust treated can be extracted. The yield can be increased by adding to the raw mixture, for aluminous cements felspar alone, and for siliceous cements felspar and some iron ore. Addition of salt to the raw mixture in one case increased the proportion of potash volatilized from 38 to 65 per cent., the percentage of total alkali in the finished cement being reduced. The volatilization ranges from 25 to 96 per cent. An average yield of about 50 per cent. soluble potash—which experience indicates may be attained—would provide about 100,000 tons of potash annually.

ALKALI FROM SILICATES.—J. S. Beckett, U.S. Pat. 1,247,619, Nov. 27th, 1917. The silicate is heated in a furnace with a basic compound and a chloride. The potassium chloride formed is extracted with water and the solution

electrolysed, the chlorine being conducted into a mixture of lime and potassium chloride, and most of the chlorate formed is separated by crystallization. The residual calcium chloride with some potassium compound is employed to treat more silicate.

POTASH FROM BLAST FURNACES.—K. M. Chance (*Cleveland Inst. Eng.*, Jan. 15th, 1918. *Chem. Trade. J.*, **62**, 44, 1918). In the burden charged into blast furnaces to produce 1,000 tons of pig-iron there is normally 15 to 30 tons of potash, or about 200,000 tons of potash per annum, of which about 50,000 tons is carried out in the blast furnace gas. The amount can be increased by adding salt to the charge, and apparently without detriment to the lining of the furnace. A company (in which the Government holds half the shares) has been formed for production of potash, and a factory has been erected in Oldbury.

ALKALIES FROM SILICATE ROCKS, etc.—F. A. Rody, U.S. Pat. 1,260,944, March 26th, 1918. Alkali in soluble form is obtained from leucite, felspar, etc., by fusing 100 parts of the silicate to a vitreous stringy mass, which after cooling and powdering (100-mesh) is digested for about an hour with water and 6 parts of lime at a pressure of 100 lb. per sq. in.

REFRACTORY MATERIAL.—C. B. Stowe, U.S. Pat. 1,265,545, May 7th, 1918. Magnesium carbonate mixed with water is shaped into articles which are coated with pulverized iron oxide and burned to expel carbon dioxide and water and to cause partial combination of the magnesia and iron oxide. Other metallic oxides may replace the iron oxide. See Eng. Pat. 110,147, Oct. 6th, 1916.

POTASH FROM CEMENT DUST.—J. G. Dean (*Chem. Met. Eng.*, **19**, 439, 1918). Relates to a wet process for extraction, by which 1 ton per day of potassium sulphate is obtained from a Californian cement works. For further particulars see abstract in *J. Soc. Chem. Ind.*, **37**, 657A, 1918.

II.—THE PHYSICAL, CHEMICAL, AND OTHER PROPERTIES OF RAW AND FINISHED PRODUCTS. TESTING.

HIGHLY PLASTIC CLAYS.—A. T. K. (*Tonwar. Ofen. Ztg.*, **41**, 190, 1917). Rohland's explanations of the plasticity of clays are the most probable, as they are borne out by experiment and deductions from actual practice. Rohland traced the plasticity of clays to their content in inorganic and organic colloid substances, the plasticity being conditioned by their coagulation. He found that the plasticity is reduced or suspended by alkaline reacting substances, but considerably increased by addition of acids, which cause coagulation of the colloids. The so-called rotting of clays is according to him due to acid reacting substances produced during the rotting process. By small addition of acids on the one hand and of substances providing colloids on the other side the process can be considerably shortened. The colloid substances included hydrated alumina, silicic acid, tannic acid, and pasty starch. It is not denied that with proper rotting of clay, ferments and enzymes also assist, of which the medium is also a colloid substance. Weber has pointed out exceptions among clays in their behaviour towards acid substances—it seems to concern those clays which contain fatty ingredients and show a contrary behaviour, since they are plainly stiffened by alkalies, presumably through a kind of saponification of the substances. Such abnormal clays are found in Saxony.

Rohland's observations are of importance in connection with the solution of two eminently practical problems: that of the increase of plasticity of lean

clays and that of the decrease of plasticity in highly plastic clays, which can scarcely be used technically or only with difficulty. Highly plastic clays, besides incapacity for further absorption of water, have also the peculiarity of not being able to be arbitrarily mixed homogeneously with other less plastic clays. This depends on the property of colloids, in the coagulated state (gels) of being unable by addition of water, and on their incapacity to take up anything at all from another colloid in this condition. Such highly plastic clays, as those (*e.g.*) occurring in Silesia, are distinguished by a high loss on ignition (to 14 per cent. and more), owing to their greater content of organic substances. In the raw state as got from the mines they are thoroughly impervious to water, dry unequally, and have a total contraction (drying and firing) of 13 to 15 per cent., as against about 8 per cent. total contraction for normally workable clays usually. Only clays with small quantities of colloid substances, which latter are not completely coagulated, can be mixed homogeneously with others which are in the same condition.

Addition or production of acid in clays—for increasing plasticity—can be attained practically by acid fermentation of the organic ingredients of the added water or by addition of dung water with controlled lowering of temperature, further through the addition of colloid substances before rotting, as is done for technical purposes to a great extent in America, consisting in the addition of hydrated silicic acid, hydrated alumina, hydrated oxide of iron, and also humic acid (German patent 201,404). For laboratory purposes tungstic acid, molybdic acid, hydrated oxide of manganese, as well as organic substances like pasty starch, tannin, catechu, caramel, gluten, etc., prove to be suitable colloid substances for this purpose. With increase of plasticity the binding power of the clays increases, but they essentially lose in plasticity through the introduction of lean materials, and after drying they lose in strength.

The opposite process enables us in the case of highly plastic clays which are themselves difficult to work to obtain a correct degree of plasticity by the use of alkaline substances and a slight rise of temperature (which can be attained by vigorous agitation). Since the alkalinity only needs to be small, lime water is available technically, or in case for certain purposes this alkalinity is not sufficient, a small addition of soda-lye to the lime water may be made. In such a way are highly plastic clays—mostly black—with their plasticity decreased made specially suitable for glass furnaces, against which less plastic clays poor in colloids are quite unsuitable for this purpose. (German patents 158,496 and 159,193). Every kind of clay demands individual treatment respecting the concentration of the alkali addition. By very small addition at first an increase of plasticity may arise, and in its place with further addition of alkali liquefaction may take place; regard must also be had to the kind of organic substances, since those of fatty nature behave abnormally.

The following clays are placed in order of suitability for such a process for reducing their plasticity: 1, Schwepnitz (Saxony); 2, Wergersdorf (Saxony); 3, Löthain-Meissen (Saxony); Klingenberg (on the Main); Frauenstadt (Posen); Wildstein (Bohemia); Colditz (Saxony); Grossalmerode (Hesse); Zettlitz.

NEW REFRACTORY MATERIALS FROM FUSED BAUXITE.—N. Lecesne (*Cer.*, **20**, 41, 1917). Relates to a new method of fusing bauxite, and its application in the production of special refractory materials. See TRANS., **17**, 192, 1918.

REFRACTORY PRODUCTS AND SALTY COALS.—(*Cer.*, **20**, 61, 179, 1917). During carbonization of coal containing common salt the walls of the coke ovens rapidly deteriorate and require frequent repairs and renewals. Wear does not proceed from high temperatures, seeing that it is produced in the interior of the oven on the faces where the temperature was lowest. The difficulty is increased with the coals of certain districts, as South Yorkshire, North Derbyshire, North Staffordshire. Wales, on the other hand, is favoured. Geologists have not been able to explain these regional peculiarities.

A few personal observations might throw light on certain aspects of the problem, such as affect the carbonization industries in the refractory products used.

As the washing of coal intended for coking has become so general, it would seem at first view that the soluble common salt would be completely removed by the water, but it is not so. The mixture of the salt with carbonaceous material is apparently very intimate, and the coal is not porous in the ordinary sense. Even when the coal is pulverized, extraction by water is very imperfect.

The action of sodium chloride on the surface of clay (bricks, etc.) has not necessarily a very injurious effect, even when repeated often. In works making salt-glazed bricks, the walls and arches of the kilns are submitted continuously for many years to an atmosphere much richer in sodium chloride vapour than that of the coke oven during carbonization.

What is produced is that the surface of the refractory brick is attacked, and an enamel of silicate of soda and aluminium is formed. This coat once applied to the exposed face, the salt vapour penetrates very slightly or not at all to the refractory brick itself. In order to be assured of this partial immunity against deteriorations the essential condition is that the salt vapour shall not come in contact with the argillaceous surface before the temperature of the latter is high enough for the whole compound produced to be in a state of fusion. This temperature is about 1,200° C. At a lower temperature the result is quite different, and in its practical effects much more serious. Combination could be produced between substances which have sufficient chemical affinity, even when the two substances are in the solid state. The combination of lime with silica or with alumina, at a temperature much below the fusing point of either component or of the compound formed, is perhaps the most impressive example of this phenomenon, and has been completely demonstrated. We can expect to find below the temperature for salt glazing, not only penetration of salt vapour into the interior of every porous brick, but a fixation of the salt (which has thus penetrated) by chemical combination with the original alumina and silica.

Finely ground calcined clay was mixed with considerable excess of common salt, and the temperature was gradually elevated to 1,200° C. in works' furnaces for 72 hours. The test mixture, most of the sodium chloride of which was volatilised, was washed repeatedly until the water no longer contained traces of soluble salt, and the residue was then analysed. Its formula was approximately $Na_2O.2Al_2O_3.7SiO_2$, indicating nearly the same degree of fixation of soda that is found also in felspar.

Deductions drawn from laboratory experiments lead us to this point. But by another kind of observation, in the case of labour on a large scale, we have learned more. In the usual type of salt glaze kiln the salt is not applied at the fire, and for this reason does not reach the interior of the kiln before the temperature of fusion of the enamel which is formed has been practically attained; and the excess of salt vapour passes away directly by the chimney. In a continuous gas kiln for salt glazing it was observed that a little salt vapour traversed the chamber where the glazing was effected and passed into another where the temperature was lower. Examination of a brick from this second chamber when salting was finished showed, in addition, the formation of a slight brownish tint on the yellow face of the brick. Meanwhile, when the temperature of the second chamber was raised to prepare it for salting, the face of most of the bricks was covered with swellings; and to a certain depth below the turgidity the clay was semi-vitrified and divided into cells. A chemical examination showed soda there in great quantity. In this case then, as in ordinary salt glazing, reciprocal action had taken place between the salt and the clay; but the difference between the chambers full of swollen and cellular bricks on the one hand, and on the other of bricks with smooth enamel and regular form, prove clearly that the conditions in the first case—and not merely the presence of salt and clay—were the determining causes of the injurious effect. These conditions determine the penetration of the porous brick by salt vapour below the temperature at which an enamel

can be formed, the formation in the solid state of compounds between soda and the brick substance, and finally exhaustion and fusion of the body of the brick, as well as of the face, when the temperature was raised sufficiently at a later stage. Laboratory experiments made by C. P. Finn have proved definitely the volatilization of iron in the form of chloride from plastic clay, and its subsequent deposition as oxide, in favorable conditions. The same verification has been made on a large scale, when a current of salt vapour acts on bricks in the course of salt glazing before being completely mixed with air and products of combustion.

In bricks lining a coke oven another change in structure below the face, which may be produced even in the absence of salt, can have its own influence in the production of disintegration. That is the deposition of particles of carbon held in the pores of the refractory brick, by decomposition of methane and other hydrocarbons present in the gas expelled from coal during its carbonization. Another change which merits taking into consideration is the reduction, by the gas, of iron in the refractory brick from the ferric to the ferrous state, its power of fusion being thereby appreciably increased. Such action may take place locally.

On p. 179 is a short supplementary article bearing on the same subject.

SILICA BRICKS.—A. Grisard (*Cer.*, **20**, 73, 1917). Notes of recollections of a journey among the chief silica brick factories in Germany. It has long been assumed that the exceptional hardness and slight expansion of German silica bricks was owing to a special agglomerating material known only to the Germans. Ten years ago the author visited, with the chief engineer of the Martin furnaces at a great steel works in the East, the chief factories of silica bricks such as those of Willich at Homburg on the Rhine, Scheidauer at Duisburg, Zurbig, Stollberg, Euskirchen, and afterwards, accompanied by M. Laeis, machine manufacturer at Trêves, the refractory products portion of the Phœnix works at Hoërd near Dortmund. This last was managed by Dr. Lange.

The visitors acquired the conviction that there was nothing of the nature of a secret agglomerating material. The superiority of the German silica bricks consisted merely in the quite special quality of their quartz supplies, of which the great majority came from beds situated in the Westerwald on the banks of the Rhine

The different kinds of quartz hitherto met with in France have an insignificant content in alumina. The quartz employed in Germany has a content of 1½ to 3 per cent. The quartz was used by all in the raw condition, and nowhere after previous calcination, and as agglomerating agent was used simply 2 to 3 per cent. of milk of lime; some add ½ to 1 per cent. of very aluminous earth, but many used only milk of lime. The quartz was previously washed in special washing cylinders to remove vegetable and other impurities.

Generally the bricks were made by hand; a few only used presses, among others Hoërd, who employed a hydraulic press supplied by M. Laeis, who acted as guide. For burning the bricks, all had intermittent down-draught kilns, round or rectangular; Hoërd alone had a gas kiln with small compartments of 12 tons. These bricks were burned at cone 14, about 1,410° C., or No. 141 of the French decimal standards of Guérineau. Manufacturers attached great importance to the burning, to the nature of the fuel employed, and above all to the cooling of the kilns which were hermetically closed as soon as the burning terminated, and the products were only drawn when they were completely cooled.

In the author's opinion, the solution of the problem consists in finding a quartz similar to the German quartz as holding 1½ to 2 per cent. of alumina, on condition, however, that the fusing point of this quartz is not below 1,800° C. It is to that content in alumina of their quartz that the exceptional hardness of their products and their proved slight expansion in Martin furnaces are due.

Some manufacturers extol the use of iron ore in the proportion of 1 to 2 per cent.; in reality, German bricks in the arch of the Martin melted slightly

from the first tappings, and in melting formed a protective glaze which assured a long duration of the arch. Perhaps, according to the nature of the quartz, that means can be used, but not so for the laboratory and the abutment.

To sum up, the silica brick should be manufactured:—

1. Exclusively of raw quartz.
2. With a judicious proportion of the grinding distributed into flour, medium grain and large angular grain.
3. Pressed by means of hydraulic presses at high pressure.
4. Burned to decimal standard 141 completely flattened, standard 143 slightly inclined.

The Germans mostly do not press their bricks; the Americans, it appears, obtain by means of high pressures good bauxite and magnesite bricks without agglomerating substances. Every satisfaction should therefore be got with hydraulic presses for silica bricks.

It is suggested that geologists and others should look out for sources of quartz in France, and that suitable tests should be made.

PROPERTIES OF SILICA BRICKS.—E. Bourry (*Cer.*, **20**, 105, 1917). In order to fulfil satisfactorily the purpose of silica bricks used in metallurgical operations, the siliceous minerals of which they are made should meet the following conditions:—1. Resistance to a temperature above 1,700° C. 2. Grains not pulverulent, in part relatively large (3 to 5 mm.), angular or lamellar, but not rounded. 3. Possibility of being heated without disintegrating or cracking.

Fusibility.—Pure silica melts at above 1,800° C., but the fusing point is lowered when the silica is mixed with even a very small quantity of other substances, the lowering of temperature being nearly proportional to the percentage of foreign matter. Thus silica bricks containing 3 to 5 per cent. of impurities melt between 1,790° and 1,750° C.

Bricks for steel furnaces should resist a temperature of at least 1,700° C., so the permissible maximum of foreign matters is 5 per cent. As 1½ to 2 per cent. of lime is added to the silica in making bricks, the siliceous mineral should have at least 97 per cent. of silica. The substances which make up the maximum 3 per cent. of impurities are iron oxide, alumina, lime, magnesia, and alkalies, rarely other substances in appreciable quantities. These bodies are probably, more or less in a state of combination, in isolated grains in the midst of the silica. That is certainly the case with oxide of iron, which forms very characteristic brown stains on the bricks when the burning temperature has been high enough.

Some consider a certain proportion of impurities indispensable for making good bricks; others attribute an important part, among these impurities, sometimes to iron oxide, sometimes to aluminium. Such hypotheses are probably based on errors of observation; at all events no account has been kept of them in mineralogical researches.

Texture.—As the high content of silica required for thermal resistance excludes the use of agglomerating agents in making the bricks, the silica grains should become felted with one another, leaving as few voids as possible. Minerals with round grains should therefore be excluded, which eliminates nearly all sands that are pure enough. Compact siliceous minerals, having crystalline structure, all give in grinding grains of suitable form. But the grains must not be too fine. A certain proportion of impalpable powder was believed to facilitate moulding by giving more plasticity to the body. That was correct, but this facility resulted in too great friability of the products after burning. This obligation of having a raw material with grains large enough and little impalpable powder eliminates not only fine sands but friable siliceous rocks which are too easily pulverized in the grinding.

Expansion.—Most siliceous minerals when heated gradually up to their fusing point show two successive increases of volume. The first is produced suddenly about 600° C., the second much more slowly, beginning at 1,400° C. Certain siliceous minerals either do not show the first expansion or at least it is little evident. These are the only ones which in present technical ceramics

can be utilised for the manufacture of silica bricks, answering the demands of metallurgists.

The first expansion in reality results in cracking the silica grains, because during the burning the temperature of the outside of these grains is necessarily higher than that of the interior so that internal tensions become stronger than cohesion. Bricks moulded with similar materials are friable, if they do not also become exhausted. The author suggests the possibility of remedying this fault by previously heating the minerals and grinding them after this first burning. That is done for the pebbles used in the manufacture of earthenware.

The second expansion begins to be perceptible at 1,400° C., but the temperature must be raised towards 1,450° or 1,500° C. in order that it may be produced freely. It has the effect, although increasing the volume of the brick, of reducing the voids existing among the grains, and of rendering the products notably more resistant. It has not the same disintegrating effects as the first because it is slower, and at this temperature the silica is doubtless less brittle. Further, the thin viscous coat of silicate of lime which at this temperature cuts into the silica grains facilitates their mutual displacement. It is known that this second expansion is not finished by the firing, and that the silica bricks continue to increase in volume in the furnaces where they are used when the temperature there is high enough.

Tests.—From what precedes, the tests to be made on siliceous minerals in order to report if they are suitable for making good bricks are the following:

1. *Texture.*—If sands, examination of the grains with a lens; if they are round or too fine, the sand is to be rejected. If rocks, to report if they are not too friable to shock, in which case they are likewise to be rejected.

2. *Expansion.*—To heat samples at a bright red heat, and leave to cool in the air. If the material cracks it cannot be used.

These two tests can easily be made on the spot.

3. *Chemical Composition.*—The material should contain at least 97 per cent. of silica. A first summary test should be made in order to eliminate all minerals containing too much impurity, and a stricter determination only for those which were satisfactory in the first analysis.

4. *Manufacturing Test.*—Minerals found good according to these three tests have many chances of being suitable for the manufacture of silica bricks. It is proper to make a manufacturing test, using about a ton of raw material. If the bricks obtained appear good they may be submitted to the following two tests:—

5. *Fusibility.*—Determination of fusing point by comparison with new French decimal standards. The bricks should not melt before standard 175.

6. *Crushing Strength.*—Hitherto it has not been determined (to the author's knowledge) what minimum load per square cm. silica bricks should be able to support. For the moment it will suffice to proceed to comparative tests with bricks that have already received the sanction of practice.

Bricks made with raw materials so selected as to give satisfaction in the two tests 5 and 6 can without fear be utilised in steel furnaces. It is useless at this time to wait months for the making of tests. It is suggested that the distribution of tests, to both laboratory and works, might be advantageously carried on by some central organization, whose expenses should be covered voluntarily by those who may profit by the activities of such organization.

The author concludes with a reminder that silica bricks were first made by Weston Young in Wales, and that Emile Muller was the first who succeeded in making them on the Continent from pulverized quartz. Young's process has been used ever since, even in Germany, and the only merit of the Germans was the finding of suitable quartzites in their own land. The prodigious development of their metallurgy has done the rest. Though the French metallurgical industry has suffered through occupation of important centres, the English, American, Russian, Italian, and Japanese make more steel than before, without constraint for want of products, of material, or of German ceramists.

STONEWARE PIPES, STOP-COCKS, etc.—W. F. Schauten (*Chem. Appar.*, **4**, 49, 60, 1917). A general description of the various forms, etc., with 36 illustrations.

STRENGTH OF STONEWARE TUBES AGAINST INTERNAL PRESSURE.—W. F. Sch. (*Chem. Appar.*, **4**, 189, 1917). A report of some investigations made at Innsbruck. Taken from *Ziegel und Zement*, p. 145, 1917. The breaking strains ranged from 17·8 to 88·7 kg. per square cm. in samples from eleven different factories.

SPECIFIC HEAT OF SOLID BODIES.—R. Schulze (*Chem. Appar.*, **4**, 134, 1917). A very brief account (with figure) of a simple apparatus for relative determination of the specific heat of the solids.

REFRACTORY MATERIALS.—O. Boudouard (*Cer.*, **20**, 158, 1917). Relates to a conference held (March 28th, 1917) at the Conservatoire National des Arts et Metiers. A general review of the subject. American results for fusibility of various refractory materials and products (magnesia, chromite, silica, bricks of different materials, etc.) are quoted. Chemical analyses of a few materials are also given.

TESTING REFRACTORY MATERIALS.—C. E. Nesbitt and M. E. Bell (*Cer.*, **20**, 175, 1917). A description of practical methods of testing, including some results.

REFRACTORIES FOR STEEL FURNACES.—W. J. Brooke (*Brick Pot. Tr. J.*, **25**, 147, 1917). See TRANS., **16**, 205, 1917.

WHAT HAPPENS WHEN CLAY IS HEATED.—Le Chatelier and Bogitch (*Brick Pot. Tr. J.*, **25**, 154, 1917). Abstract of paper from *Comptes Rendus* relating to crushing strengths of hot bricks. See also TRANS., **16**, Abs. 90, 1917.

HOW EXPRESSION ROLLS WORK.—(*Brick Pot. Tr. J.*, **25**, 174, 1917). A brief discussion of their action on materials like clay.

HOT AND COLD SIZES OF FIREBRICKS.—(*Brick Pot. Tr. J.*, **25**, 177, 1917). See TRANS., **16**, 270, 1917.

FUSED SILICA.—F. Bottomley (*Brick Pot. Tr. J.*, **25**, 195, 1917). See TRANS., **16**, Abs. 52, 1917.

REFRACTORY PROPERTIES OF SILICA.—Le Chatelier and Bogitch (*Brick Pot. Tr. J.*, **25**, 217, 1917). See TRANS., **17**, 10, 1918.

MOLER BRICKS.—(*Brick Pot. Tr. J.*, **25**, 216, 1917). A brief note relating to very light bricks much used in Norway, and named from the Molererde or diatomaceous earth of which they are made. The moler earth resembles kieselguhr, but contains few of the long narrow diatoms found in the latter. It is usually very impure from contamination with clay, sand, and volcanic dust, and can be improved by careful washing if all the clay is not removed. Most moler bricks are made from the crude material. Kieselguhr needs the addition of a bond for making into bricks.

Moler bricks are made by mixing the earth with a little water, passing it through crushing rolls, and then tempering it in a pan-mill. Bricks are made from the paste by machines which imitate the hand moulding process, or by extrusion presses.

Well-made moler bricks have a crushing strength of 1,400 lb. per sq. in., and usually weigh 3¼ lb. (about one-third the weight of an ordinary clay brick). When mixed with sawdust, naphthalene, etc., moler earth can be made into bricks specifically lighter than water, sometimes as little as 350 oz. per cub. ft. These very light bricks are particularly good insulators.

To produce similar bricks from kieselguhr, asbestos or other fibrous material must also be added as a bond, no such addition being necessary with moler earth.

Moler earth consists chiefly of colloidal silica with iron oxide, alumina, etc.

PUMICE BRICKS.—(*Brick Pot. Tr. J.*, **25**, 224, 1917). These have long been used on the Continent, where they are called "Schwemmsteine." True pumice bricks are made of a natural lava dust corresponding to a pumice sand, which is mixed with hydraulic lime and water, moulded into bricks, and left to set, but not burned. True pumice bricks are soft to the touch and easily broken by rough handling. They are very light—about one-third the weight of clay bricks of similar size. They make excellent heat insulators, when not subjected to too high a temperature, but will not carry much load (and therefore not beams or joists). Probably kieselguhr or diatomite would form an efficient substitute for the pumice sand.

CRISTOBALITE AND TRIDYMITE IN SILICA BRICKS.—(*Brick Pot. Tr. J.*, **25**, 225, 1917). Based on a paper by H. Le Chatelier. See TRANS., **16**, Abs. 55, 1917.

BRITISH ELECTRICAL PORCELAIN.—H. Watkin (*Brick Pot. Tr. J.*, **25**, 233, 1917). A brief account of its manufacture and uses, taken from the *Times Trade Supplement*.

ELECTRICAL PORCELAIN.—L. E. Barringer (*Brick Pot. Tr. J.*, **25**, 239, 1917). See TRANS., **16**, Abs. 77, 1917.

ASBESTOS (BLUE AND WHITE).—(*Quarry*, **22**, 52, 1917). Relates to the differences between the blue asbestos or crocidolite of South Africa, and the white asbestos or chrysotile of Canada. As regards composition the former averages about 51 per cent. silica, 35 per cent. ferrous oxide, 7 per cent. soda, 2 per cent. magnesia, and less than 5 per cent. water, whereas chrysotile averages about 39 per cent. silica, 41 magnesia, 3 ferrous oxide, and 14 water, with sometimes 3 per cent. or more alumina.

Some varieties of chrysotile have been known to withstand a temperature of 5,000° F. without being perceptibly affected. Its softness also makes it easier for milling and reduction, and also specially suitable for gland packings, etc. Crocidolite has a fibre which is said to be lighter, longer, stronger, finer, and more elastic, and it is also a better insulating material as regards heat.

ZIRCONIA AS A REFRACTORY MATERIAL.—(*Quarry*, **22**, 87, 1917). See TRANS., **16**, 121, 1917 (paper by J. A. Audley).

ZIRCONIA CRUCIBLES.—(*Quarry*, **22**, 103, 1917). See TRANS., **16**, 121, 1917 (paper by J. A. Audley).

SPALLING OF MAGNESITE BRICKS.—(*Quarry*, **22**, 87, 1917). See TRANS., **16**, 85, 1917 (paper by J. W. Mellor).

TEMPERATURE MEASUREMENTS IN CLAY WORKS PRACTICE.—(*Quarry*, **22**, 87, 1917). See TRANS., **16**, 118, 1917. (Lecture by J. W. Cobb)

REFRACTORY MATERIALS IN SOUTH YORKSHIRE.—W. G. Fearnsides (*Quarry*, **22**, 8, 1917). Report of a paper relating to refractory clays, ganister, and dolomite.

FIREBRICKS IN OXIDIZING AND REDUCING ATMOSPHERES.—(*Quarry*, **22**, 142, 1917). See TRANS., **16**, 268, 1917 (paper by J. W. Mellor).

BAUXITE AS A REFRACTORY.—(*Quarry*, **22**, 88, 1917). Refers to a letter of the elder Le Chatelier concerning the use of bauxite as a refractory lining for furnaces.

PHYSICAL PROPERTIES OF COKE OVEN BRICK MATERIALS.—W. G. Fearnsides (*Quarry*, **22**, 57, 83, 1917). Report of a lecture dealing chiefly with fireclays and siliceous materials, and mixtures of these.

REFRACTORY MATERIALS USED IN THE IRON AND STEEL INDUSTRY.—C. Johns (*Quarry*, **22**, 113, 1917). See TRANS., **16**, Abs. 47, 1917.

REFRACTORY PROPERTIES OF SILICA BRICKS.—Le Chatelier and Bogitch (*Quarry*, **22**, 140, 1917). See paper in TRANS., **17**, 10, 1918.

INDIAN MAGNESITE.—(*Quarry*, **22**, 36, 1917). A brief notice of a paper on "The Magnesite Mines of India," by C. H. B. Burlton, referring more particularly to the Salem magnesite, a typical analysis of which is given.

MELTING POINTS OF REFRACTORY MATERIALS.—(*Quarry*, **22**, 132, 1917). Brief notes from paper by Barr in *Industrial Engineering*. See also TRANS., **17**, Abs. 96, 1918.

SOME USES OF SANDS.—P. G. H. Boswell (*Quarry*, **22**, 40, 1917). Extracts from a memoir on "British Resources of Sands suitable for Glass Making." On p. 25, 26, is a review of the same work.

ZIRCONIA AS A REFRACTORY MATERIAL.—J. A. Audley (*Pot. Gaz.*, **42**, 384, 1917). See TRANS., **16**, 121, 1917.

SPALLING OF MAGNESITE BRICKS.—J. W Mellor (*Pot. Gaz.*, **42**, 385, 1917). See TRANS., **16**, 385, 1917.

TEMPERATURE MEASUREMENTS IN CLAY WORKS PRACTICE.—J. W. Cobb (*Pot. Gaz.*, **42**, 386, 1917). See TRANS., **16**, 118, 1917.

BAUXITE AS A REFRACTORY MATERIAL.—(*Pot. Gaz.*, **42**, 502, 1917). A short note from "*Revue de la Metallurgie*."

FIRECLAY FROM A MANUFACTURER'S POINT OF VIEW.—G. H. Timmis (*Pot. Gaz.*, **42**, 596, 1917). See TRANS., **16**, 197, 1917.

REFRACTORIES FOR STEEL FURNACES FROM THE CONSUMER'S POINT OF VIEW.—W. J. Brooke (*Pot. Gaz.*, **42**, 596, 1917). See TRANS., **16**, 205, 1917.

BLACK CORES IN FIRECLAY GOODS.—J. W. Mellor (*Pot. Gaz.*, **42**, 598, 1917). See TRANS., **16**, 259, 1917.

THE TEXTURE OF FIRECLAYS.—W. C. Hancock and W. E. King (*Pot. Gaz.*, **42**, 781, 1917). Report of paper read before the Society of Chemical Industry. See also TRANS., **16**, Abs. 60, 1917.

CHEMICAL PORCELAIN.—H. Watkin (*Pot. Gaz.*, **42**, 781, 1917). Report of paper read before the Society of Chemical Industry. See also TRANS., **16**, Abs. 59, 1917

SANDS FOR GLASS MANUFACTURE, etc.—P. G. H. Boswell (*Pot. Gaz.*, **42**, 782, 1917). Report of paper read before the Society of Chemical Industry. See also TRANS., **16**, Abs. 61, 1917.

FUSED BAUXITE (NEW REFRACTORY MATERIALS).—(*Pot. Gaz.*, **42**, 789, 1917.) Translated from article in *La Cèramique*. See also TRANS., **17**, 192, 1918.

SAGGAR-MAKING.—G. Simcoe (*Pot. Gaz.*, **42**, 883, 1917). Reprint from *Trans Amer. Cer. Soc.*, vol. 17. See also TRANS., **16**, Abs. 17, 1917.

SCIENTIFIC AND INDUSTRIAL RESEARCH.—(*Pot. Gaz.*, **42**, 973, 1917) The second annual report of the Council for Scientific and Industrial Research.

EFFECT OF PRESSURE ON CONTRACTION, TENSILE STRENGTH, AND CRAZING.—E. Watkin (*Pot. Gaz.*, **42**, 978, 1917). See TRANS., **17**, 111, 1918.

ACID AND BASIC FURNACE LININGS.—J. E. Foster (*Pot. Gaz.*, **42**, 243, 1917). See also TRANS., **16**, 24, 1917.

TESTING OF REFRACTORY MATERIALS.—J. W. Mellor (*Pot. Gaz.*, **42**, 1,068, 1917). See also TRANS., **17**, 90, 1918.

REFRACTORY PROPERTIES OF SILICA.—Le Chatelier and Bogitch (*Pot. Gaz.*, **42**, 1,068, 1917). See also TRANS., **17**, 1, 10, 1918.

STUDY OF BONE CHINA BODY, II.—W. H. Yates (*Pot. Gaz.*, **42**, 1,185, 1917). Relates to contraction at different temperatures. It is again proved that bone in limited amount acts as a flux, but more than 20 per cent. seems to have a refractory influence on the mixture.

MANUFACTURE OF SILICA BRICKS.—C. E. Nesbitt and M. L. Bell (*Brick*, **51**, 127, 1917). See TRANS., **16**, Abs. 76, 1917.

SLAG TESTS FOR REFRACTORY BRICKS.—C. E. Nesbitt and M. L. Bell (*Brick*, **51**, 518, 1917). See TRANS., **17**, Abs. 72, 1918.

REFRACTORY BRICKS.—(*Brick*, **51**, 211, 1917). A brief account of the properties of silica, lime, chromite bricks, bauxite bricks, magnesite bricks, and fireclay bricks. It is stated in connection with silica bricks that practice has given 1·5 to 3 per cent. of lime as the limits, with about 1·8 for the best results

REFRACTORY MATERIALS.—A. V. Bleininger (*Brick*, **51**, 945, 1917). A review of the properties of the constituents of refractory materials, and the adaptation of such materials to fireclays are of three grades, softening respectively at cone 31 or higher, cone 28 to 31, and below cone 28. Clays may also be divided into two classes according as they are plastic, and dense burning at about 1,200° C., or open burning (retaining their porosity), the clays of the second class being also usually less plastic.

In the burning of silica bricks (usually to above 1,500° C.), the lime bond forms a monocalcium silicate and the quartz is transformed—practically completely, in industrial practice, as K. Seaver has shown—into cristobalite, usually accompanied by expansion of $\frac{3}{8}$ to $\frac{7}{16}$ inch per linear foot over the mould dimensions of the silica bricks.

Bauxite and mixtures of bauxite and fireclay have been much used, and have proved in some cases successful substitutes for magnesite. Besides being liable to high shrinkage on heating, bauxite tends to contract also under pressure at furnace temperatures, and thus is not so suitable where severe load conditions prevail. Usually a good fireclay is used to bond together the calcined bauxite, and the resulting firebricks have not generally a softening temperature above 1,800° C.

Reference is also made to magnesite, carbon refractories, pure fused magnesia or alumina, zirconia, spinel, etc. Tables are given of (1) Deformation of firebricks when reheated to 1,300° and 1,350° C. under different loads; (2) Values of K for different kinds of firebrick; (3) Wologdine's thermal conductivity coefficients for different refractories.

PROPERTIES OF CLAYWARES.—B. T. Sweely (*Brick*, **51**, 299, 399, 1917). The results of an investigation by the author. Results show that increase in the water used in forming clayware up to the point where it starts to form a slip, will result in a denser finished product, other things being equal. A clay should apparently be worked as soft as practicable. The increase in density seems to be due to the very dense packing of the clay grains during drying.

Results also show that by varying the pressures by varying the size of a given shaped orifice on an auger machine, with a clay of constant consistency:

1. The specific gravity of the wet clay column did not vary.
2. The absorption of the burned clay did not vary.
3. Lamination increased as the size of die decreased, probably owing to increased friction area per unit weight of clay.
4. The power per unit weight of clay was found to vary almost directly as the friction area of the exuded column.

On p. 602 A. V. Bleininger comments on some criticisms.

ELECTRICAL RESISTIVITY OF PORCELAIN AND MAGNESIA AT HIGH TEMPERATURES.—P. H. Brace (*Trans. Amer. Electrochemical Soc.*, **33**, 205, 1918). Tests were made of the electrical resistivity from 439° to 990° C. of (1) electrically fused magnesia (prepared from fairly pure calcined magnesia, and free from cracks and blow-holes), (2) similar material crushed and moulded under heavy pressure, then fired at above 1,700° C., (3) porcelain of the kind used for spark-plug insulators. Direct current was used for the tests, but was applied alternately in both directions. The apparent resistivity was found to be a function of the duration of the application of the test voltage. When the voltage was reversed after the resistance had become nearly constant, a low value was found, the value rising with time as at first. Repeated reversals had the same result. The calcined magnesite was found to have higher resistivity than the porcelain, also higher ratio of initial to final resistivity at each temperature, and the resistivity comes to steady value more quickly. The moulded sample of magnesia showed somewhat lower values of resistivity than the other, possibly because of additional impurities introduced during grinding and firing.

At the two highest temperatures the porcelain was found to behave like a storage battery. Upon disconnecting the test voltage an electromotive force in the opposite direction was found which was sufficient to force a measurable current through the sample. The electromotive force decayed slowly and was still appreciable after half-an-hour. The initial value was about 0·7 volt.

CRUSHING STRENGTH OF MAGNESIA-SILICA MIXTURES AT HIGH TEMPERATURES.—O. L. Kowalke and O. A. Hougen (*Trans. Amer. Electrochemical Soc.*, **33**, 215, 1918). It was found that the mechanical strength of magnesia at high temperatures was in general increased by the addition of other oxides (Al_2O_3, Cr_2O_3, TiO_2, SiO_2, ZrO_2), and that silica gave the best results.

Pure magnesia was mixed with varying proportions of silica, the ground mixtures moistened with 10 per cent. (found most effective) of water, pressed into cylinders at 1,500 lb. per sq. inch, dried, and baked at about 2,100° C. Cylinders so prepared were adjusted by grinding and subjected to pressure at various temperatures. Maximum strength was in mixtures with 7½ per cent. silica.

Prolonged heating above 1,900° C. produces great loss in weight, this loss increasing rapidly about 2,000° C., because of destructive action of carbon upon magnesia as well as silica.

Increased temperature and duration of baking increases the subsequent strength of the cylinders, but prolonged heating above 1,900° C. must be avoided.

The minerals periclase and forsterite were identified in thin sections of the cylinders, the forsterite being only formed to a slight extent below 1,500° C. Between 1,700° C. and 1,800° C. the crystals of forsterite grow rapidly in number and size, and finally form a complete envelope about the periclase apparently cementing the grains of the latter. Above 2,000° C. this envelope of forsterite, owing to surface tension, collects into separate crystals, and when the forsterite softens the cementing power is weakened.

Pure magnesia, melting at 2,800° C., has the property of bonding itself 1,000° C. below its melting point to form a hard mass. It failed under a load of 66·5 lb. per sq. inch at 1,680° C., but with about 7½ per cent. silica the

failure occurred only at about 1,870° C. The failure of magnesia cylinders is slow and gradual, that of magnesia-silica cylinders being abrupt.

Apparatus is described and illustrated, and several microphotographs are given.

A LENGTH COMPARATOR FOR DETERMINING LINEAR EXPANSION.—L. de Banfre (*Cassier's Eng. M.*, **51**, 244, 1917). An illustrated description of the method and appliances.

FLOW OF VISCOUS LIQUIDS THROUGH PIPES.—(*Cassier's Eng. M.*, **51**, 76, 1917). A brief digest of a paper by W. K. Lewis in *J. Ind. Eng. Chem.*

THE SAND BLAST.—F. George (*Cassier's Eng. M.*, **51**, 9, 169, 239, 303, 1917). A comprehensive account of the theory and development of this important operation. The different systems or methods are described, with illustrations, viz., suction, vacuum, steam suction, sand-slurry, and pressure or blast.

HOW SLAG TEMPERATURES AFFECT FIREBRICKS.—R. M. Howe (*Brick*, **54**, 143, 1919). A record of tests made at temperatures of 1,150°, 1,250°, 1,350° and 1,450° C. with six different slags (composition given), whose melting points ranged from 1,020° to 1,400° C. Three types of firebricks were used, and the results of the tests are presented in tabular form. The penetration was found to increase to a marked extent with rise of temperature, especially at the higher temperatures.

ZIRCONIUM AND ITS COMPOUNDS.—(*Eng. Min. J.*, **105**, 330, 1918). An article on properties and uses. Zirconium can be obtained in crystalline, graphitoidal, and amorphous forms. Pure malleable zirconium is useful as a substitute for platinum. The new alloy ferro-zirconium is used in the steel industry for removal of nitrogen and oxides from steel. The most recent such alloy contains 40—90 per cent. zirconium, the remainder being iron or a metal of the iron group, with small quantities of titanium and aluminium (U.S. Pat. 1,151,160). These alloys do not readily oxidize, and resist the action of chemicals. They have metallic lustre and take a polish resembling silver or steel. They are malleable, and should be useful for incandescent lamp filaments, as they require a smaller consumption of current then the ordinary metal filament lamp. The alloys are produced either by reducing with aluminium powder the mixed oxides (of iron, titanium, etc.), or by heating the mixture of oxides in graphite crucibles in the electric furnace; either zircon or native zirconia is used as raw material. Ferro-zirconium is used as scavenger (deoxidizer) according to English patent 29,376; the alloy contains 20 per cent. zirconium, and 1 per cent. by weight is used with the steel. In America zirconia of 98—99 per cent. purity will soon be on the market at the wholesale price of about 60 cents per pound. German patent 289,292 (of Feb. 8th, 1914) protects the use of zirconia as a surface coating for quartz, bauxite, or similar refractory or other substances or objects. Zirconia has also been used for the production of laboratory ware, in connection with which the researches of C. N. Johnson have been specially important. Combustion tubes of zirconia are gas-tight at temperatures up to 1,000° C.

Other properties and uses of zirconia are alluded to. (An abstract of this paper at somewhat greater length will be found in *Zeits. angew. Chemie.*, **31**, 363 Ref., 1918)

ACID-PROOF AND FIREPROOF NATURAL ROCK.—H. Fussbahn (*Zeits. angew. Chemie*, **31**, 48, 1918). For production of concentration plant, Glover towers, denitrating towers, Gay-Lussac towers, etc., hitherto burned ceramic and lava materials have been used. H. Buchmeyer now recommends for such purposes a naturally occurring siliceous material, which is said to possess more than six times the durability of the materials generally used.

ROSENTHAL PORCELAIN FOR CHEMICAL AND TECHNICAL PURPOSES.—F. Singer (*Zeits. angew. Chemie*, 31, 221, 227, 229, 1918). Deals largely with glass-like porcelain. A discussion of the properties desirable in special porcelains for chemical and technical purposes, the most important being resistance to abrupt changes of temperature and to chemical reagents. To compensate for the disadvantages caused by greater expansion on heating, as compared with quartz glass, porcelain and glass must possess sufficient elasticity, tensile and bending strength, and tenacity of materials, and also internal tensions should be absent.

The resistance of good porcelain bodies is traceable to their content of sillimanite, which resists even hydrofluoric acid. Normal porcelain bodies have nearly equal parts of plastic and non-plastic materials, the latter consisting of about equal parts of quartz and felspar. The first firing of the porcelain takes place at about 800° C., and the glost firing at about 1,400—1,450° C., the mass being thoroughly sintered while the glaze forms a transparent glassy covering. The expansion coefficient of porcelain after burning at cone 15 is only about half of what it would be for the same material fired at 1,000° C. Hence the firing temperature for chemical and technical porcelain should be as high as possible.

Resistance of porcelain to temperature changes increases with the content of clay substance, and with equal clay substance the less felspar and the more quartz the better. Porcelain rich in felspar cracks very easily whether the clay substance be normal, very high, or very low. This is explained by increase of expansion coefficient with increasing felspar, and increase of elasticity with increasing quartz. These conclusions are confirmed in practice.

The highest clay substance content in porcelain is about 55 per cent., and this with equal parts of felspar and quartz gives the best result for resisting temperature changes. With further increase of clay, more felspar would be necessary to make it compact. The content of clay substance and felspar indicated suffice for products of good quality.

For useful porcelains, glazes with 8 to 10 SiO_2 are generally good, but for laboratory porcelains 12 to 16 SiO_2 should be employed, with extra alumina accordingly, since glazes relatively poor in silica and alumina melt too soon, and owing to lower viscosity at the higher temperature tend to flow. These glazes rich in silica and alumina are specially resistant towards chemical attacks, especially when the fluxes include as much calcium and magnesium as possible at the expense of the alkalies.

It should be remembered that even if the coefficient of expansion be the same for body and glaze, tensions may arise from unequal cooling, because ceramic bodies are bad conductors of heat. To meet the requirements of such conditions, elasticity, tensile strength, and compressive strength are needed.

As a test of satisfactory adjustment between glaze and body, a large quantity of glaze is melted in a cup or bowl so as to produce a thick cake of glaze. With proper agreement there should be neither cracking of the cup nor crazing of the glaze, either during cooling or afterwards. With other conditions the same, glass or glaze stands sudden heating better than sudden cooling. The thickness of a glaze has an important influence, and here the elasticity becomes of greater consequence.

Satisfactory behaviour under the melted cake test indicates that porcelain otherwise good will meet the highest demands connected with change of temperature. Laboratory basins and crucibles can be heated over a naked flame, and cooking vessels can in like manner be used on the open hearth. It is even possible with the oxyhydrogen blowpipe flame to melt holes in the walls of porcelain crucibles, and join on tubes, an operation involving complete agreement of the expansion coefficients of the body, glaze, glass melted from these two, and all intermediate products. This has been accomplished with the Rosenthal porcelain.

Particulars are given of various tests of Rosenthal porcelain in comparison with pieces of Berlin porcelain of the same shape, there being little to choose between the two in the results. An important test was a quenching test, the porcelain at 290° being plunged into water at 20°.

It has been found practicable to work the Rosenthal porcelain in the same manner as glass, though its melting point is as high as cone 32 or 1,710° C. Porcelain tubes may be bent, melted, blown, fixed together, and holes may be melted in particular pieces and tubes joined on, etc.

A detailed account is given of tests made with vessels intended for use in the storage and transport of liquid air. It is claimed that for various reasons the porcelain is better for this purpose than either glass or metal.

On p. 248 of the same volume, E. Moser asserts that the ordinary hard porcelain of Berlin is susceptible of the same treatment as the Rosenthal porcelain, and that there is therefore nothing new in the glass-like fusible porcelain, and that no fuss had been made of that feature hitherto simply because there was no demand for it.

On p. 103 of the next volume (32, 1919) Singer replies to Moser, maintaining his previous statements, and pointing out that he had given due credit to the Berlin porcelain.

PROPERTIES OF SOME OHIO AND PENNSYLVANIA STONEWARE CLAYS.—H. G. Schurecht (*J. Amer. Cer. Soc.*, **1**, 267, 1918). Report of investigations on a number of samples. With few exceptions, screening through a 150-mesh sieve was found to improve the strength of the raw and burned clays, to increase the dry porosity, to lower the vitrification temperature, to widen the vitrification range, to diminish the minimum burned porosity, to increase the burning shrinkage, and to increase the density in the burned condition.

When ground and screened (150-mesh) the residue from the washing may in most cases be advantageously added to the washed clay. Addition of felspar with or without a little calcium carbonate lowers the vitrification temperature. When a large proportion (6·1 per cent.) of calcium carbonate is added, the bodies are more porous at the lower temperatures, the vitrification temperature it raised, and the vitrification range is generally narrowed.

The maximum strength of all the clays tested is developed by burning to cone 8. No relation apparently exists between softening temperature and resistance to warpage under load at the low temperatures, the more refractory clays sometimes falling before the less refractory ones. Mechanical strength falls very much when the clays are burned above cone 1. In one case (a No. 1 fireclay) the modulus of rupture was 270 in the dry state, but only 27 at cone 4. The run of mine clays, screened dry through a 20-mesh sieve, seem more resistant to quenching treatment than the same clays screened through a 150-mesh sieve. Many of the results may be applied to other ceramic industries besides chemical stoneware.

USE OF DENSE SOLUTIONS IN DETERMINING THE STRUCTURE OF PORCELAINS.—H. Spurrier (*J. Amer. Cer. Soc.*, **1**, 287, 1918). The use of dense solutions was suggested by variations in specific gravity of spark plug insulators. Slightly underfired porcelain has a higher specific gravity than a properly fired piece, and overfired pieces have a lower specific gravity than a properly fired piece. As a suitable liquid potassium mercuric iodide meets all requirements except that it is expensive. Acid mercuric nitrate has all the desirable properties. Two solutions of acid mercuric nitrate are used, one diluted so as to just float a properly fired piece, and to let an underfired piece sink, the other allowing a properly fired piece to sink and an overfired piece to float. The solutions tend to become rather denser, but this is easily remedied by adding water with a little nitric acid.

LABORATORY TESTING OF SILICA BRICKS.—R. J. Montgomery and L. R. Office (*J. Amer. Cer. Soc.*, **1**, 338, 1918). A general discussion of the value of various tests, including load test, crushing strength, specific gravity, etc. The paper is followed by an interesting discussion.

POROSITY AND VOLUME CHANGES OF CLAY FIREBRICKS AT FURNACE TEMPERATURES.—G. A. Loomis (*J. Amer. Cer. Soc.*, **1**, 384,

1918). The following is a summary of results and conclusions: (1) Bricks capable of withstanding 40 lb. per square inch at 1,350° C. generally show slight changes in volume or in porosity when burned at temperatures up to 1,425° C. (2) Most bricks which failed to pass the load tests show rather marked changes in volume or in porosity at some temperature below 1,425° C. (3) Bricks which show over-burning by pronounced expansion at temperatures below 1,400° C. invariably fail in the load test. The adoption of a definite limit for the permissible expansion within the given temperature range is particularly important for detecting inferior clay refractories. The limit for expansion should be lower than that for allowable contraction. (4) The changes in volume and in porosity of bricks burned at some temperature between 1,350° C. and 1,425° C. serves in a measure as a criterion of their ability to pass the load test. (5) Most bricks which show a porosity decrease below 5 per cent., and a volume change under 3 per cent. (about 1 per cent. linear) when burned at 1,400° C. will pass the load test. (6) Bricks which show a decrease in porosity above 5 per cent., or an expansion or contraction of more than 3 per cent. by volume (1 per cent. in length) at 1,400° C., nearly always fail to pass the load test. (7) The use of limiting porosity and volume changes for clay firebricks burned at 1,400° C. would serve to eliminate many bricks which fail in the load test. (8) Bricks which fail in the load test—due to failure in the bond—may not show marked changes in volume or porosity in burning, but often show very low cold crushing strength. (9) No definite relationship seems to exist between the softening point of a firebrick and its ability to withstand load at high temperatures. However, all bricks which softened below cone 28, whether siliceous in character or not, failed in the load test. Cone 28 might therefore be specified as the minimum softening point for any clay firebrick. Bricks with less than 65 per cent. silica should probably have a minimum softening point of cone 31.

CALCULATION OF RATIONAL ANALYSIS OF CLAYS.—H. S. Washington (*J. Amer. Cer. Soc.*, 1, 405, 1918). The author holds that the usual methods of carrying out the rational analysis of clays cannot give reliable results, and proceeds to explain a simple and expeditious method of calculating the mineral composition of a mixture of silicates from the chemical analysis, and to describe a modification adapted to the mineralogical characters of clays.

The so-called "norm" of igneous rocks is the expression of the chemical composition in terms of certain mineral molecules which are assumed to be (and in most cases are) present in the rock. The actual mineralogical composition of a rock is called the "mode," while the rock is classified by the standard molecular composition expressed in the "norm." With clays, the problem and the calculation are generally much simpler than with rocks, since in most clays the only essential minerals are "kaolin," quartz, and the felspars, the micas being of secondary importance.

The chemical (or ultimate) composition of clay is expressed as made up of silica, alumina, ferric oxide, magnesia, lime, potash, soda, water, with sometimes small amounts of titanium dioxide and carbon dioxide, and very small and negligible amounts of other constituents. In mineralogical or "modal" composition, all clays are essentially mixtures of "kaolin" (=Kl or $Al_2O_3.2SiO_2.2H_2O$), quartz (=Q), and the felspars, orthoclase (=Or or $K_2O.Al_2O_3.6SiO_2$), albite (=Ab or $Na_2O.Al_2O_3.6SiO_2$), and anorthite (=An or $CaO.Al_2O_3.2SiO_2$); in some clays, small amounts of muscovite (=Mu or $2H_2O.K_2O.3Al_2O_3.6SiO_2$) occur; in some cases the clay substance may be wholly or partly in the form of halloysite or other material differing from the "kaolin" only in the proportion of water present in combination.

To find the mineral composition of a clay from the analysis the percentage amounts of the several constituents are divided by the respective molecular weights—silica 60, alumina 102, water 18, potash 94, soda 62, lime 56, giving the relative numbers of molecules. Water is only present in kaolinite, where 2 molecules are combined with 2 of silica and 1 of alumina; in the felspars there is one molecule of potash, soda, or lime, with one molecule of alumina, and 6 molecules of silica in orthoclase and albite, but only 2 in anorthite.

Assuming orthoclase to be the only felspar in a clay, a molecular amount of alumina equivalent to the potash shown by the analysis is taken, with six times the equivalent amount of silica; this gives the molecular amount of orthoclase (molecular weight 556, that of albite being 524, anorthite 278, and kaolinite 258). The rest of the alumina goes to kaolinite, with twice the equivalent amount of silica and twice the equivalent amount of water. Excess silica represents quartz, and excess water represents moisture. The molecular amounts of orthoclase, kaolinite, and quartz thus obtained have only to be multiplied by the molecular weight of the corresponding mineral in order to give percentages; the molecular amount of a mineral is merely the molecular number of the constituent oxide of which only one molecule is present in the mineral (of alumina in kaolinite, of potash or alumina in orthoclase). Thus in the case of a clay containing 63·36 per cent. of silica, 24·28 alumina, 3·29 potash, and 9·07 per cent. water, by dividing these percentages by 60, 102, 94 and 18 respectively, the molecular numbers obtained are 1·056 silica, 0·238 alumina, 0·035 potash, and 0·504 water. The orthoclase is obtained by multiplying its molecular weight (556) by the unit molecular weight present, 0·035, giving 19·46 Or. Deducting the 0·035 alumina required for orthoclase, the remainder, 0·203 belongs to kaolinite, and multiplying by the molecular weight of the latter (258) the percentage of kaolinite, 52·37 Kl is obtained. Subtracting from the total molecular amount of silica (1·056) the amounts required for orthoclase and kaolinite ($6\times0{\cdot}035=0{\cdot}210$, and $2\times0{\cdot}203=0{\cdot}406$, together 0·616), the remainder 0·440, multiplied by the molecular weight of quartz, 60, gives 26·40 Q, as the percentage of quartz. Subtracting the water in the kaolinite, 0·406, from the total molecular amount of water, 0·504, and multiplying the remaining 0·098 by 18, gives the percentage of moisture, 1·76 Aq. If albite and anorthite are to be taken into account, molecular amounts of alumina equivalent to those of soda and lime must be set aside for the formation of those minerals, along with silica equivalent to six times that of the soda to form albite, and twice that of the lime to form anorthite. Assuming the accuracy of the chemical analysis, results thus calculated are far more reliable than any rational analysis by the usual methods.

In more complicated cases, ferric oxide may be assumed to be present as limonite (Lm), $Fe_2O_3.H_2O$. An example is worked out. If carbon dioxide (molecular weight 44) is present, it is assumed to be in calcite (calcium carbonate, molecular weight 100); an equivalent amount of lime is allotted to the carbon dioxide to make up calcite, which is reckoned by multiplying the molecular number of carbon dioxide by 100, the rest of the lime being calculated to anorthite. Magnesia (molecular weight 40) may be assumed to be present in chlorite, into which biotite (magnesian mica) usually alters, but it is best treated on the assumption that it enters serpentine, $3MgO.2SiO_2.2H_2O$ (molecular weight 276), the unit of calculation being one-third of the molecular number of the magnesia present; any error involved is negligible. Muscovite (potash mica) is the mica more commonly present in clays, but in small amount, and for all practical purposes its potash and alumina may be calculated as orthoclase and kaolinite. Tables are given comparing the results obtained by calculation with results obtained by rational analysis, accompanied by critical comments. An alternative method of calculation is briefly alluded to.

THE PRESERVATION OF BUILDING STONE.—C. H. Desch (*J. Soc. Chem. Ind.*, **37**, 118T, 1918). The method of protecting building stone by means of certain soluble silicofluorides, first used by Kessler (Eng. Pat. 4,954, 1883), is free from all the objectionable features possessed by other methods. The silicofluorides of magnesium, zinc, and aluminium are stable salts which dissolve in water forming slightly acid solutions, and produce only insoluble products with calcium carbonate . In the case of magnesium silicofluoride the insoluble protective layer formed as a result of its action on calcium carbonate (carbon dioxide being evolved) is composed of silica and magnesium and calcium fluorides. The author found the application of such acid solutions

thoroughly effective in preserving even very porous limestones against disintegration, and in reducing the porosity of those exposed to weather. When the limestone is of very open texture it is advisable to brush the surface with a cream made of dust of the same stone and water, allowing this to fill the pores before applying the silicofluoride solution. This helps to form a compact layer without altering the appearance of the stone.

Magnesium and zinc silicofluorides are crystalline substances which readily dissolve in water. Aluminium silicofluoride, which has certain advantages when used on very porous limestones does not crystallize well, and is usually replaced by the double salt of aluminium and zinc. All the compounds and their products are colourless, so the treatment does not alter the appearance of the stone, and the hardness of the limestone is increased considerably. Copper and other coloured silicofluorides have been used for producing coloured surfaces on stone.

The silicofluorides, commercially known as "fluates," have been manufactured at Clermont-Ferrand, and apparently nowhere else, and have been largely used in France for protecting stone. They are supplied in a solid state, and are only dissolved when wanted for use.

THE PRESERVATION OF DECAYING STONE.—A. P. Laurie and C. Ranken (*J. Soc. Chem. Ind.*, **37**, 137T, 1918). The authors found that the addition of a little glycerin to water solutions sufficed to prevent the deposition of substances in the outer layer of a stone, though not in the case of organic solvents (alcohol, etc).

They found that bricks made by compression from ground Ketton stone (limestone) with zinc and magnesium fluosilicates (silicofluorides) failed to form permanent bricks, but were crumbly after two weeks.

The authors concluded that very many colloid precipitates, such as silica and alumina, cannot be regarded as cementing materials. They also concluded that the solid resulting from the solution or solutions should be uniformly distributed throughout the stone, and not merely over the surface, that the resulting cement should not be readily attacked by air, water, or the acids usually in rain water, and that the production of a binding material should not depend upon destruction of the natural cementing material of the stone.

ZIRCONIA AS A REFRACTORY.—E. H. Rodd (*J. Soc. Chem. Ind.*, **37**, 213R, 1918). A brief review of the occurrence and properties of zirconia. Zirconia possesses a remarkable combination of desirable refractory properties, marred chiefly by a tendency to form a nitride or carbide at high temperatures under certain conditions. Reference is made to various German investigations. The refractory properties of even the crude commercial material are very high. A heavy reddish-brown powder (of specific gravity 4·4—5·3) contained about $68{\cdot}9ZrO_2.14{\cdot}08ZrSiO_4.12{\cdot}22SiO_2.3{\cdot}6Fe_2O_3.0{\cdot}6TiO_2$. It is said to have been used very successfully for lining Siemens-Martin furnaces, anhydrous tar being employed as a binder. When properly fired zirconia bricks are very hard and strong.

Rather more than half the iron in crude zirconia can be removed by treatment with acids, but complete separation from iron and other impurities necessitates dissolving the whole.

TESTING HARDNESS OF METALS.—J. W. Craggs (*J. Soc. Chem. Ind.*, **37**, 43T, 1918). A general review, with special references to the Brinell test, Shore's scleroscope, Pellin test, Turner's sclerometer, Martens' sclerometer, and Saniter's abrasion test.

SOLUBLE GLASS.—R. M. Caven (*J. Soc. Chem. Ind.*, **37**, 63T, 1918). Soda-glass with silica to soda as 2 to 1 by weight is technically known as "alkaline silicate," with the ratio 3 to 1, or more, it is "neutral silicate." These silicates consist probably of solid, anhydrous solutions of the monosilicate, Na_2SiO_3, or perhaps the disilicate, $Na_2Si_2O_5$, in excess of silica.

To be technically effective, soda-glass must be dissolved in water. This is true whether it is to be used as a viscous solution or in the solid state. The solution is now prepared by heating the broken glass with water to about 150° C. under a steam pressure of about 5 atmospheres. A dilute solution is thus obtained, which is evaporated to give the necessary strength, but it cannot easily be evaporated to dryness, because a skin forms on the surface of the colloidal liquid as it becomes concentrated, and intumescence occurs later, so that a more or less solidified froth eventually results.

A solid, soluble glass is obtained by grinding the nearly insoluble glass either dry or with water, and suitably heating the product, thoroughly mixed with a little water, until a vitreous solid is obtained, which easily and almost completely dissolves even in cold water. In the solution of soda-glass, excess of water hinders solution, and reducing the amount—down to a certain minimum—promotes it. If the glass is to be dissolved effectively in water the minimum amount of water must be employed, and if the glass can dissolve as a whole without preferential solution of soda this will also take place with the minimum amount of water.

The conditions for the production of a hard, vitreous, soluble, hydrated soda-glass are the following: 1. The anhydrous glass should pass through a sieve with 50 meshes to the linear inch in the case of the neutral glass, though a sieve of 20 meshes suffices for the alkaline glass. The powder should not be unduly exposed to the air, since it readily absorbs water and carbon dioxide, especially the alkaline silicate. 2. Sufficient but not too much water must be mixed with the pulverised glass; the weight of water should be between 25 and 38 per cent. of the weight of glass. 3. The mixture should be heated sufficiently but not too strongly—say in a flat cake tin, coated inside with lime and loosely covered. The initial temperature of about 70° should, after about four hours' heating, not exceed 100° C.

The product may be ground, and is practically permanent in the air.

The theory of the process is discussed, and also the colour of anhydrous and hydrated soda-glass.

HYDRATION OF ANHYDRITE AND DEAD-BURNED GYPSUM.—A. C. Gill (*J. Amer. Cer. Soc.*, 1, 65, 1918). A small bottle was charged with small lumps of anhydrite, filled with water, and closed with a metallic screw-cap. A similar bottle was charged with several lumps of alabaster (which had been heated for 3½ hours to a maximum temperature of 560° C.), filled with water, and closed in the same way. Six years later the water was found to have completely evaporated from both. The anhydrite fragments were firmly cemented by gypsum crystals, and the hydration was not limited to the amount of calcium sulphate which could be held in solution at one time.

The pieces of burned alabaster had become completely covered with fine bristling gypsum needles about ⅛ in. in length, and inside the spiny coating the mass had set to much greater hardness than ordinary plaster of Paris. In this case the bottle was cracked by the expansive force of hydration or by the growing force of the gypsum crystals.

BONDING STRENGTHS OF CLAYS UP TO RED HEAT.—C. W. Saxe and O. S. Buckner (*J. Amer. Cer. Soc.*, 1, 113, 1918). Report of investigation on the bonding strengths of a number of clays between normal temperature and red heat, that is, during drying and the early stages of burning. The following conclusions were reached: The strength of a clay, dried to constant weight at a final temperature of 110° C., is only a rough measure of its strength at conditions which prevail in most factories. Such results serve to distinguish strong clays from weak clays, but do not distinguish between (say) a number of fairly strong clays at conditions under which they are likely to be used. Different clays imperfectly dried or exposed to a more or less moist atmosphere show great dissimilarity in their affinity for water. The strength of clays (while hot) between 110° C. and red heat is considerably lower for the first 200° or 300° than their cold strength when thoroughly dried at a final temperature of 110° C. During dehydration, both the hot and cold strength of clays

increases or remains practically constant, being little affected by the physical and chemical changes during this period. Generally the strongest clays in the cold condition as dried at 55° C. are the strongest when hot during the interval of lowest strength between 110° and 325° C., hence the former can be taken as a rough measure of strength during this interval.

TESTS OF CLAYS AND LIMES BY PLASTICIMETER.—F. A. Kirkpatrick and W. B. Orange (*J. Amer. Cer. Soc.*, **1**, 170, 1918). Report of results obtained with the "Bureau of Standards Plasticimeter" (described by W. E. Emley in *Trans Amer. Cer. Soc.*, **19**, 523, 1917) on limes, clays, and porcelain bodies. The instrument can distinguish between finishing and non-finishing varieties of hydrated limes. It also seems to give an indication of the behaviour of clays in jiggering, but does not serve for correlating plasticity with any other physical properties.

EFFECT OF ELECTROLYTES ON SOME PROPERTIES OF CLAYS.—H. G. Schurecht (*J. Amer. Cer. Soc.*, **1**, 201, 1918). Report of investigation of the effects of adding to clays 0·05, 0·10, 0·15, 0·20, 0·40, 0·60, 0·80, 1·00, 1·50, 2·00, 3·00, and 5·00 by weight of electrolyte (sodium hydroxide, sodium silicate, sodium carbonate, calcium hydroxide, tannic acid, and sulphuric acid). The clays used were Kentucky ball clay alone, and the same mixed with equal parts of flint and grog respectively, and also similar mixtures of flint with Tennessee ball clay and Georgia kaolin respectively. The following is a summary of the results. The strength of clays when dry may be increased by the addition of the following electrolytes (named in order of effectiveness): sodium hydroxide, sodium silicate, sodium carbonate, tannic acid, and calcium hydroxide. The addition of sodium hydroxide increases the strength of some of the mixtures as much as 400 per cent. Small percentages of sulphuric acid decrease the strength of Kentucky ball clay. More than 2·0 per cent. of calcium hydroxide decreases the strength of Kentucky ball clay. Addition of 0·80 to 2·5 per cent. of caustic soda affects adversely the moulding properties of the bodies, which is also the case to a lesser extent with additions of sodium silicate, sodium carbonate, or more than 2·0 per cent. of sulphuric acid; addition of less than 2·0 per cent. of sulphuric acid improves the moulding properties. Addition of 1·0 to 2·0 per cent. of alkalies decreases the volume shrinkages of the ball clay and flint mixtures, but increases that of the kaolin and flint mixture. Addition of sodium hydroxide to Kentucky ball clay increases shrinkage. Sulphuric acid in small percentages increases shrinkage, and in larger percentages decreases shrinkage. Tannic acid and calcium hydroxide increase shrinkage.

Addition of alkalies and acids increases the densities of the clays and mixtures when dry. Up to 1·0 per cent. calcium hydroxide increases the density, but larger amounts decrease the density. Porosity is lowered by alkalies and increased by acids in small percentages. Large additions of acid decrease porosity. Calcium hydroxide increases porosity. Burning shrinkage at cone 01 is lowered by small percentages of caustic soda, and increased by larger quantities. Sodium hydroxide increases the density and decreases the porosity in the burned condition.

The addition of the following electrolytes (named in order of effectiveness) to the bodies in the plastic condition increases the strength of pieces burned to cone 8: sodium hydroxide, sodium silicate, sodium carbonate, and tannic acid.

In the discussion it was pointed out that the addition of alkalies increased the tendency of the clays to crack in drying.

SINTERING OF MAGNESIA.—J. B. Ferguson (*J. Amer. Cer. Soc.*, **1**, 439, 1918). A note describing how some silky, calcined, pure magnesia powder (used for separating the two heaters in a special electric resistance furnace of the cascade type) was found to be sintered after keeping the furnace for some hours at temperatures ranging from 1,600° to 1,720° C. There was no binding material, but interwoven crystals of periclase with less than 0·5 per cent. of forsterite ($2MgO.SiO_2$).

SILICA REFRACTORIES.—D. W. Ross (*J. Amer. Cer. Soc.*, **1**, 477, 1918). An illustrated account of work done and results obtained in connection with the raw materials, the manufacture and burning, and the properties of the burned products. Several tables of data are included.

As a rule, the quartzites most suitable for silica bricks are those which range from the slightly porous to the highly metamorphosed impervious rocks —having tightly interlocking grains. Those quartzites which crush largely by a breaking through of the original grains are apt to yield silica bricks of lower porosity than those in which the breaking is largely through the interstitial material between the built up grains, or those in which the original grains break free from the interstitial material.

The porosity of a finished silica brick depends primarily upon the porosity of the unburned mixture. Maintaining the temperature of the kiln at 1,250° to 1,350° C. until a large percentage of the quartz in the bricks has been transformed into the low specific gravity forms, and then slowly proceeding to the higher temperatures, should result in a low porosity brick of low specific gravity.

The specific gravity of a silica brick serves as a quick means of determining the degree to which the original quartz has been transformed to the lower specific gravity forms of silica. But to obtain a comprehensive idea of the qualities of any variety of silica bricks the other properties, such as porosity, cold cross-breaking strength, softening temperature, behaviour in the load test, and appearance in thin section under the microscope should also be determined.

A PYCNOMETER OPERATED AS A VOLUMETER.—H. G. Schurecht (*J. Amer. Cer. Soc.*, **1**, 556, 1918). An illustrated description. The bottle is filled with kerosene or water, and, as the stopper is inserted, sufficient liquid is forced in to completely fill the tube in the stopper. The excess liquid is carefully wiped off and the bottle weighed. The briquette to be measured is then inserted in the bottle, and the operation is repeated. Then if V = volume, W = weight of bottle plus liquid, $W1$ = weight of bottle plus liquid plus briquette, B = weight of saturated briquette, and S = specific gravity of liquid, $V = (W - W1 + B) / S$.

Compared with the Seger volumeter hitherto used, it is claimed that this type of volumeter is much more rapid, more accurate, less easily broken, less expensive, etc.

SPALLING OF SEWER PIPE.—C. W. Parmelee (*J. Amer. Cer. Soc.*, **1**, 660, 1918). The flaking of the outside surfaces was found to be connected with the presence of small geodes (small hollow bodies with the inner face of the cavity lined with small crystals). These small geodes were all lined with quartz crystals.

COMPOSITION OF CHINESE CELADON POTTERY.—J. S. Laird (*J. Amer. Cer. Soc.*, **1**, 675, 1918). Report of analyses, etc., of two specimens found at the sites of ancient kilns at King-te-chen. For comparison other analyses of old and modern celadon glazes and the corresponding bodies are given.

CERTAIN CHARACTERISTICS OF PORCELAIN.—A. V. Bleininger (*J. Amer. Cer. Soc.*, **1**, 697, 1918). Porcelains vary widely in such physical properties as modulus of elasticity, coefficient of thermal expansion, heat conductivity and electrical resistance at different temperatures. The amounts of undissolved quartz or cristobalite, of glassy matrix, of undecomposed clay and of sillimanite fluctuate within wide variations. The development of sillimanite is desirable owing to its stability, its freedom from transformation changes, its density (3·031), and its low coefficient of thermal expansion. The thermal expansion is decreased by replacing quartz by clay, sillimanite, fused alumina, zirconia, or other substances not subject to molecular transformations. The body obtained with zirconia seemed particularly suitable for purposes where high mechanical strength is necessary.

The electrical conductivity of vitrified bodies increases with temperature according to the law of compound interest at the rate of about 2 per cent. per degree C.

Felspar is the important factor in lowering the electrical resistance, and porcelain is improved in this respect by substituting synthetic silicates containing beryllium oxide, magnesia, or other alkaline earths, for the felspar.

For porcelains intended to be used under severe electrical and heat conditions, it would seem desirable to eliminate both the quartz and the felspar as constituents of the body in the manner suggested above.

SAGGAR CLAYS AND MIXTURES.—G. H. Brown (*J. Amer. Cer. Soc.*, 1, 716, 1918). A so-called low-grade or cheap clay will often produce a more durable saggar than some of the so-called high-grade clays, but the suitability of the clay for the purpose should always be considered.

Saggar failures may be due to rough handling of either unburned or burned saggars, to too rapid heating during the first firing, to breakage during cooling, or to deformation of loaded saggars at the maximum kiln temperatures.

Breakage in handling of unburned saggars depends largely on the strength of the dried saggar clays. Some clays are stronger than others, but the size and proportioning of the grog particles, and the percentage of grog used, also have their effect. Careful supervision of the placing should reduce the breakage, both of the green saggars and those which have been fired. In the case of the latter a vitrifying wad clay has an injurious effect when it has to be forcibly removed from saggars. Breakage during the first firing may arise either from the saggars not being dry enough when set in the oven, and the water too suddenly changed into vapour, or by similar action of heat on the combined water.

A large proportion of the breakage of saggars seems to take place during cooling, and this depends on the rate of cooling, for any clay product will crack if cooled rapidly enough, and even fused silica ware. Deformation of saggars causes failure chiefly where large and heavy wares are concerned, and with high firing temperatures.

The requisite properties of saggars include refractoriness, mechanical strength, resistance to deformation, and resistance to temperature changes.

The softening or fusion point of a clay is not a safe criterion for saggars. The mechanical strength of a fired saggar (cold) depends on the extent of vitrification of the bond clays, on the size and proportioning of the grog particles, on the presence or absence of hair cracks, on the proportion of grog to clay, and the uniformity of mixing and tempering. These several points are discussed.

A good proportion to use for saggars is about 50 per cent. grog, 20 per cent. vitrifying clay, and 30 per cent. open-burning clay.

Kaolin would be valuable in saggar mixtures, because while it is highly refractory and open burning, it does not contain excessive amounts of sand like the sandy open-burning fireclays. Even as little as 10 per cent. kaolin improves the refractoriness and other qualities of saggar mixtures.

The ordinary wet pan gives a much better mixing of clays than a soaking-pit, and also permits more grog to be used without loss of its working properties, because it develops the maximum plasticity of the bond clays. Increased grog content gives lower shrinkage.

INFLUENCE OF GRAIN SIZE OF NON-PLASTIC MATERIALS ON THE BEHAVIOUR OF FINE CERAMIC BODIES IN FIRING.—R. Rieke (*Sprech.*, **51**, 95, 101, 103, 108, 112, 117, 121, 124, 129, 135, 1918). Report of results obtained with three different kinds of bodies, a typical hard porcelain body with 55 per cent. clay substance, 22·5 felspar and 22·5 quartz, a soft porcelain body (corresponding to Seger porcelain) consisting of 25 per cent. clay substance, 30 felspar, and 45 quartz, and a hard earthenware body with 35 per cent. clay substance, 5 felspar, and 60 quartz. For all the bodies were used washed Zettlitz kaolin (with 98·5 per cent. clay substance), Norwegian felspar (microcline), and Hohenbocka quartz sand.

The effects of firing (at different temperatures, the various modifications of the body mixtures) on contraction, specific gravity and porosity are discussed. With long heating above 1,300° C. the change of the quartz into cristobalite is first noticeable, the complete change of unpulverized sand requiring 11 or 12 firings at cone 15.

As regards the earthenware compositions, it was found that the drying contraction became smaller with increasing fineness of the sand, and up to cone 4 the firing contraction was greater the finer the sand; beyond cone 4 scarcely any increase of contraction was perceptible, so that the same differences were mostly found. Porosity was as a rule also greater the finer the sand, but at cone 11 it only varied between 14·5 and 15·2 per cent., and also at cone 13—14 the differences were unimportant. Bodies with finer sand undergo their principal changes—recognisable as greater increase in contraction and corresponding increase in water-absorbing power—at lower temperatures, whilst these changes in bodies with coarser quartz took place at higher temperatures and in smaller measure.

To an initial increase of the specific gravity (traceable to the behaviour of the kaolin) follows above cone 05 (to cone 16—17) a gradual decrease, which gets greater with increasing fineness of the sand, notably from cone 9. This change is to be explained partly by the action of the melted felspar, but the strong decrease of specific gravity at high temperatures appears to be caused also by the increased speed of change of the quartz owing to increase of total surface. It is noteworthy that all the five modifications of the earthenware body after firing at high temperature, in spite of differences in specific gravity showed no important differences in the power of absorbing water (that is, porosity). At low temperatures porosity increases with increasing fineness of the quartz.

With all fine ceramic bodies the grain size of the ingredients has extraordinarily great influence upon the behaviour of the bodies in firing, upon the sintering temperature, and upon the physical structure.

It is concluded from the results of the tests that, without changing the rational composition of a body, its properties (expansion coefficient, resistance to temperature changes, specific gravity, strength, transparency, etc.) may be influenced in high degree by suitable choice of raw materials and their grain size, as well as by the firing temperature.

TRANSPARENCY OF PORCELAIN VESSELS.—T. Hertwig (*Sprech.*, **51**, 188, 1918). The author quotes Dorfner's conclusion that all porcelains with insufficient transparency are not fritted, and his opinion that it is not absolutely necessary to fire porcelain at cone 14, but that even at lower firing temperatures very fine transparency will be produced with bodies poor in clay and quartz. From his own trials the author concludes that the firing temperature must be retained at cone 14. He also concludes that the purest transparency can only be produced by using raw materials free from (or at any rate poor in) titanium and manganese.

TRANSPARENCY OF PORCELAIN BODIES.—A. Nowak (*Sprech.*, **51**. 229, 1918). A short discussion. Transparency and colour depend on the kind and quantity of felspar used, on the fusibility ratio of glaze to body, on the grinding of the body, and on the nature of the flames of the glost firing.

INFLUENCE OF PRESSURE ON CONTRACTION, TENSILE STRENGTH, AND CRAZING.—E. Watkin (*Ker. Rund.*, **26**, 2, 1918). See TRANS., **17**, 111, 1918.

INFLUENCE OF GROG ON THE CRAZING OF DUTCH TILES.—G. Heinstein (*Ker. Rund.*, **26**, 5, 18, 1918). Trials were made of 14 body compositions including 38 or 33 per cent. plastic clay substance with 23 or 12 per cent. quartz, the remaining 39 or 55 per cent. being made up respectively of quartz calcined at cone 14, or kaolin clay-substance (raw and calcined at cone 14 respectively), felspar, and chalk; the 39 per cent. in one case consisted of

calcined (at cone 14) plastic clay-substance. Tiles of these bodies were glazed with a raw glaze consisting of 70·5 red lead, 23·1 quartz, and 6·4 Zettlitz kaolin, and fired at cone 09a. The body with 55+12 quartz showed no crazing. No distinct difference was perceived between raw and calcined quartz. Other variations were made in the composition of the body.

The author concludes that for eliminating crazing in such tiles by change in the body composition the following measures are available: Harder firing of the tile or the grog; finer grinding of grog and quartz; reduction of felspar at the expense of clay substance, quartz or chalk (the difference in the action of raw kaolin clay-substance and felspar as regards crazing is very small for the temperatures concerned); reduction of raw clay subtances with increase of quartz; reduction of quartz with increase of calcined clay substance; increase of plastic clay-substance at expense of kaolin clay-substance (both raw and calcined); increase of calcium carbonate at expense of felspar, of raw and calcined clay-substance, or of quartz; substitution of plastic clay by one which later is hard-fired and in consequence of this permits a somewhat higher temperature for melting the glaze, or by one which with other properties the same has less tendency to produce crazing, or is plastic, and accordingly can be mixed with more non-plastic material.

BENDING OF EASY-FIRED CLAYWARES.—(*Ker. Rund.*, **26**, 243, 246, 1918). See paper by B. Moore in TRANS., **17**, 351, 1918.

RELATION BETWEEN COMPOSITION AND VOLUME-WEIGHT OF GROG SANDS.—O. Mühlhæuser (*Zeits. angew. Chem.*, p. 737, 1903). Grog was made by calcining, at cone 6—7, St. Louis clay composed of 56·08 per cent. silica, 39·26 alumina, 3·09Fe_2O_3, 0·78CaO, 0·51MgO, 0·07K_2O, 0·19Na_2O. Tests were made on portions of grog from the top and bottom of the furnace, and showed for the top part porosity of 14·5, 16·7, and 16·3, with 44·9 c.c., 46·3 c.c., and 45·7 c.c., as the corresponding volumes occupied by 100 g., and for the bottom part porosity of 17·5, 17·0, and 17·9, with corresponding volume per 100 g. of 47·7, 46·2, and 46·4 c.c. respectively. In the middle the grog had porosity 16·7 per cent., the volume per 100 g. being 46·2 c.c. (of which 7·7 c.c. represents pore spaces). The specific gravity of the calcined material was 2·62, and its melting point cone 30—31.

The crushed and ground grog was graded by means of sieves 6, 8, 10, 14, 18, 20, 40, 60, 80, 100, and the mean of five tests gave the following results for the several classes:—

Class	6	8	10	14	18	20	40	60	80	100	
Vol. of 100 g.	93·6	93·5	94·8	94·5	94·0	91·0	93·0	94·1	94·7	88·4	c.c.
Wt. of 100 c.c.	106·9	106·9	105·5	105·8	106·4	109·9	107·5	106·3	105·6	113·1	g.

It would seem that absolutely pure classes possess equal volume-weights, the difference in the case of class 100 being possibly due to the presence of all classes of smaller grain size. In the following table the hollow spaces have been calculated, and specified as they have arisen in the formation of the individual classes:—

Class	6	8	10	14	18	20	
100 g. unground grog occupies	46·2	46·2	46·2	46·2	46·2	46·2	c.c.
100 g. ground and graded occupies	93·6	93·5	94·8	94·5	94·0	91·0	c.c.
Pores	47·4	47·3	48·6	48·3	47·8	44·8	c.c.
Pore-space per 100 g.	7·7	7·7	7·7	7·7	7·7	7·7	c.c.

Class	40	60	80	100	6 to 80 (incl.)	
100 g. unground grog occupies	46·2	46·2	46·2	46·2	46·2	c.c.
100 g. ground and graded occupies	93·0	94·1	94·7	88·4	93·7	c.c.
Pores	46·8	47·9	48·5	42·2	47·5	c.c.
Pore-space per 100 g.	7·7	7·7	7·7	7·7	7·7	c.c.

Grains of equal size occupy on the average 93·7 c.c. per 100 g., including 47·5 c.c. pores.

Mixtures of two classes.—The grains of class 6 were substituted successively by 5, 10, 15, and so on up to 95 per cent. of the finer classes, and results tabulated and also plotted in curves, the general results being as follows: (*a*) Substitution of finer grains for coarser grains always causes the volume-weight to increase up to a maximum and then decrease. (*b*) Classes with grains a little smaller than those of class 6 give mixtures in which maximum density is acquired very early. Classes with finer grains produce maximum density with a mixture of 60 coarse grain to 40 fine grain. (*c*) The finer the grain of a class the more it increases the volume-weight when mixed with class 6. (*d*) The densest mixture from a coarse and a fine class is obtained by mixing two classes in the following proportions:—

Grain Classes	6 & 8	6 & 10	6 & 14	6 & 18	6 & 20	6 & 40	6 & 60	6 & 80	6 & 100
Mixture proportion (g.)	80 : 20	75 : 25	60 : 40	60 : 40	60 : 40	55 : 45	60 : 40	60 : 40	60 : 40
Volume-weight	108·2	109·4	115·6	120·6	128·2	135·7	137·6	139·5	144·3

Substitution of class 100, in stages of 5 per cent. up to 95 per cent., for classes 6, 10, 18, 40, and 80 gave results tabulated in the paper. The general results are: (*a*) In mixing the finest class with a coarser class the volume-weight of the mixture increases with the size of grain. (*b*) The densest mixture of a coarse class with a fine class is obtained from the following proportions:—

Grain Classes	60 and 100	10 and 100	18 and 100	40 and 100	80 and 100
Mixture proportion ...	60 : 40	55 : 45	50 : 50	50 : 50	40 : 60
Volume weight	144·3	143·2	140·9	129·7	119·2

Composition of densest mixtures from more than two classes:—

A. Mixtures of four classes: 1. Mixtures of classes 6 and 14 is densest with 60 : 40 respectively. 2. The densest mixture from classes 6, 14, and 40 consists of 60, 40, and 35 parts by weight respectively, or 44·4, 29·6, and 25·9 per cent. 3. The densest mixture from classes 6, 14, 40, and 100 consists of 44·4, 29·6, 25·9, and 25·0 parts by weight respectively, or 35·5, 23·7, 20·7, and 20·0 per cent.

B. Mixtures of seven classes: (1). 10 and 14. (2). 10, 14, and 18. (3). 10, 14, 18, and 20. (4). 10, 14, 18, 20, and 40. (5). 10, 14, 18, 20, 40, 60. (6). 10, 14, 18, 20, 40, 60, 100. Percentage composition:—

Mixture Class	10	14	18	20	40	60	100
1	69·5	30·5	—	—	—	—	—
2	50·5	22·2	27·3	—	—	—	—
3	32·3	14·3	17·5	36·0	—	—	—
4	24·8	11·0	13·5	27·7	23·0	—	—
5	19·8	8·9	10·8	22·2	18·4	20·0	—
6	15·2	6·8	8·3	17·1	14·2	15·4	23·1

C. Mixtures of eight classes. Percentage composition:—

Mixture Class	6	10	14	18	20	40	60	100
1	75·0	25·0	—	—	—	—	—	—
2	59·5	19·8	20·7	—	—	—	—	—
3	45·8	15·3	15·8	23·1	—	—	—	—
4	35·2	11·8	12·2	17·8	23·1	—	—	—
5	27·1	9·1	9·4	13·7	17·8	23·1	—	—
6	24·6	8·3	8·5	12·5	16·2	21·0	9·1	—
7	18·2	6·1	6·3	9·2	12·0	15·6	6·8	25·9

REFRACTORY COMPOSITION.—F. M. Beckett, U.S. Pat. 1,244,688, Oct. 30th, 1917. Relates to a refractory composition containing slag formed in the manufacture of ferrochromium high in carbon.

SILICA BRICKS.—Bied (*Comptes rend.*, **166**, 776, 1918). Relates to the influence of iron oxide and lime as agglomerants. In the absence of lime no agglomerating action was perceived in a silica brick mixture containing 3, 4, or 5 per cent. of iron oxide, and no tridymite network was formed. Addition of 3 per cent. ferric oxide along with 1 per cent. lime only lowered the fusibility

5° C. A ferruginous brick after several days in an acid steel furnace had expanded 1·8 per cent. and was sound, but the quartz grains had lost their individuality.

SILICA BRICKS.—E. Rengade (*Comptes rend.*, **166**, 779, 1918). Relates to composition of bricks after use in the crown of a Siemens-Martin furnace. The author distinguished four zones. (A) The part which was in contact with the flames and was glazed, or sometimes partly fused to form stalactites. It was of a grey colour, apparently homogeneous, sometimes honeycombed. (B) A dark grey or black zone adjoining (A), but usually separated from it, homogeneous, and rather hard. (C) A transition zone often showing unconverted quartz (the larger grains) in a black matrix; the latter shades off to a clear brown in which the heterogeneous structure of the unaltered brick is visible. (D) Apparently unchanged part of the brick. Under the microscope are seen in zones (A) and (B) tridymite crystals surrounded by an opaque black matrix, but whereas the crystals are rounded by fusion in (A), they are large and transparent in (B). In passing from the hot face of the brick the amount of tridymite diminishes until the normal structure of the original brick is found. (B) is generally richer in iron than (A), probably owing to capillary attraction of the black ferruginous material from (A) between the tridymite crystals of (B); in like manner a fusible silicate containing lime seems to pass on into zone (C). The fusibility of silica bricks is not appreciably affected by the presence of a large quantity of iron oxide.

HARDNESS OF MATERIALS OF CONSTRUCTION.—H. Le Chatelier and B. Bogitch (*Comptes rend.*, **166**, 840, 1918). The Brinell ball test is applied to measure the hardness of a brick by laying on it a small square piece of lead foil 0·05 mm. thick, previously blackened by the action of sulphuretted hydrogen in slightly acid solution, then dried and smeared with vaseline, which is for the most part removed again so as to leave a matt surface. The results obtained are much more consistent than those arrived at by determining the crushing strength of bricks. The test is useful in controlling the manufacture of bricks.

ELECTRICAL RESISTIVITY OF PORCELAIN AND MAGNESIA.—P. H. Brace (*Amer. Electrochem. Soc.*, 1918). Relates to resistivity at high temperatures, especially for sparking plug insulators. Fused magnesite has higher resistivity, and a higher ratio of initial to final resistivity at each temperature than the porcelain used for sparking plugs, and the resistivity acquires a constant value sooner. See abstract in *J. Soc. Chem. Ind.*, **37**, 417A, 1918.

CRUSHING STRENGTH OF MAGNESIA-SILICA MIXTURES.—O. L. Kowalke and O. A. Hougen (*Amer. Electrochem. Soc.*, 1918). The best results were obtained with mixtures containing 7 to 8 per cent. silica, which failed at 1,870° C., whereas pure magnesia failed at 1,680° C. The failure of pure magnesia was gradual, and that of mixtures sudden. Cylinders fired at or over 1,900° C. lost weight through reaction with carbon supports. When fired below 1,500° C. little forsterite was formed, and the strength was low. Fired at 1,800° C., periclase was enveloped in and bonded with forsterite. At 2,000° C. the forsterite formed larger and separate crystals, thus reducing strength. See somewhat fuller abstract in *J. Soc. Chem. Ind.*, **37**, 417A, 1918.

REFRACTORY MATERIALS.—J. P. Leather (*Gas World*, **68**, 339, 1918). A discussion of refractory materials from a gas engineer's point of view. See Trans., **17**, 244, 1918.

TESTS FOR REFRACTORY MATERIALS.—(*Gas World*, **68**, 355, 1918). See Trans., **17**, 300, 1918.

TEXTURE OF COKE OVEN BRICKS.—W. G. Fearnsides (*Gas World*, **68**, Coking Section 15 [April], 1918). A general discussion.

THE INVERSIONS OF SILICA.—G. E. Foxwell (*Gas World*, **68**, 369, 1918). A brief survey of the subject, including Fenner's and Le Chatelier's investigations.

SALT CORROSION OF COKE OVEN WALLS.—(*Gas World*, **68**, Coking Section 20 [Feb.], 1918). An article translated from "Glückauf." The salts dissolved in the coal washing water consist of chlorides and sulphates of alkali and alkaline earth metals, and usually contain 80 to 90 per cent. sodium chloride. These salts begin to decompose about 900° C., the liberated alkali combining with ingredients of the bricks to form more easily fusible alkali silicates and aluminosilicates; these first appear as a glaze, which later cracks and peels off, exposing new material for attack, and in this way gradual destruction of the interior of the bricks takes place. The evil is mitigated by regulating the supply of fresh water so as to keep the sodium chloride below 1 gramme per litre, but this is impracticable with very salty coals. In an extreme case it was only found possible to lengthen the life of the oven walls by using a special refractory material and selecting a type of oven in which the temperature of the wall was under perfect control. The Koppers regenerative oven was chosen, and the walls were built of well-burned fine-grained acid bricks containing about 85 per cent. of silica.

The effects of corrosion on ordinary firebricks are described, and also on silica bricks, no trace of corrosion being shown in the latter. With silica bricks the thickness of the walls can be lessened, giving a better heat exchange between the coking chamber and the flues, and hence a shorter period of carbonization and increased output. But care must be taken not to lower the yield of ammonia. Walls were repaired with a cement or plaster consisting of 50 to 70 ground refractory brick, of grain size 1 to 3 mm., and 50 to 30 finely ground siliceous clay. The mixture had a softening point about 1,600° C. (cones 25—27), and contained about 88 per cent. silica, and fluxes equivalent to about 1·5 per cent. K_2O. Care is needed in laying it on.

TEXTURE OF COKE OVEN BRICKS.—W. G. Fearnsides (*Gas J.*, **141**, 589, 1918).

REFRACTORY MATERIALS.—(*Gas. J.*, **142**, 138, 1918). Review of book by A. B. Searle.

REFRACTORY MATERIALS IN GAS-WORKS.—J. P. Leather (*Gas J.*, **142**, 333, 1918). See TRANS., 17, 244, 1918.

SILICA REFRACTORY BRICKS.—H. Le Chatelier and B. Bogitch (*Gas J.*, **143**, 438, 1918). See TRANS., **17**, 10, 1918.

CORROSIVE ACTION OF FLUE DUST ON FIREBRICKS.—(*Gas J.*, **144**, 421, 1918). See TRANS., **18**, 230, 1919.

BASIC REFRACTORIES FOR THE OPEN HEARTH.—J. S. McDowell and R. M. Howe (*Bull. Amer. Inst. Min. Eng.*, No. 146, 291, 1919). Relates to magnesites and dolomitic materials. Magnesite is sold in America as bricks, as finely ground "furnace magnesite" for bricklaying, and deadburned grains for making and repairing furnace bottoms. The latter consist of grains ranging from $\frac{5}{8}$ inch (or 1·6 cm.) diameter to very fine sandy particles. Deadburned magnesite is obtained by calcining the crude or lightly burned material at a temperature that will cause sintering of the particles. A little ferric oxide seems to be necessary for the production of a satisfactory sinter., 4·5 to 8 per cent. in the deadburned grains being preferred.

Dolomite has been little used for brickmaking in the U.S., but granular calcined or "double-burned" dolomite forms the principal ingredient of several commercial materials offered for refractory purposes. Dolomitic refractories are almost confined to open-hearth and electric furnaces, where they are used for fettling (between heats) and as substitutes for magnesites in temporary patching. The hearth of the steel furnace is usually built of magnesite bricks, the brickwork being protected by a working bottom of granular deadburned magnesite, which is sintered into place in layers 1 to 2 inches (or 2·5 to 5 cms.) thick to a total depth of 12 to 18 inches in the middle of the furnace. After each heat, calcined dolomite is thrown against the banks as high as it will

stick, all holes in the bottom being filled. At the end of each week such holes are usually carefully filled with deadburned granular magnesite. For temporary patching, dolomite is generally used, because it sets more quickly and its first cost is less.

Particulars (including some analyses) are given concerning magnesites from Austria, Greece, Canada, California and Washington. The Austrian material, which was almost exclusively used before the war, was distinguished by its comparatively high content of iron oxide, and in the case of other magnesites, in order to get the proper sintering and bonding properties, it became necessary to add iron oxide and to incorporate it thoroughly by calcining at a very high temperature. This treatment, providing the magnesite was low enough in harmful impurities like silica and lime, gave a high-grade refractory. Dolomitic refractories are also referred to, which during the war have been commonly used as substitutes for grain magnesite. Latterly the tendency of steel makers has been to use specially prepared dolomites (instead of ordinary calcined dolomite) for temporary patching, and to use high-grade magnesite for all original installations and important repairs.

Dolomite may be calcined in either vertical or rotary kilns; in the latter case the rock is usually crushed to pass approximately a $\frac{5}{8}$ inch (or 16 mm.) screen, the fine powder being screened out and the granules burned. For the best results the heat must cause the decarbonated grains to shrink and become hard and dense. Often the rock is "double-burned," most of the CO_2 being driven off at one operation, and a second heat treatment at a higher temperature causing further shrinkage. The usual range of composition of the crude rock is 28 to 35 per cent. lime, 14 to 20 magnesia, 1 to 7 silica, 0 to 14 alumina, 0·5 to 5 ferric oxide, 43 to 46 carbon dioxide.

Ordinary calcined dolomite slakes easily in air, and so should be made just before use. In a furnace with a dolomite bottom the gas is best kept on even during shutdowns, or a new bottom may be needed on starting up again, which is never the case with good magnesite. Dolomite does not set as solidly as magnesite, so patches are more liable to become detached and float in the bath.

Special dolomitic refractories (supplied under various trade names) are more resistant than ordinary calcined dolomite to air slaking, and give better service in the furnace. In most of them the granules are coated or impregnated with pulverized basic slag, iron ore, or similar material by burning at a high temperature in a rotary kiln. Another plan tried is to coat the crushed rock with a pulverized slag suspension in water, so that upon burning a protective coat will be formed on the surface. In other cases the slaking properties are weakened by using impure dolomite (preferably high in iron).

The wearing away of the basic bottom is due to the abrasive action of the slag and metal frothing during the process of oxidation, the scouring out of holes caused by boiling when the heat becomes excessive, chemical reactions between constituents of the hearth and of the bath or slag, and perhaps other minor causes.

Tests were carried out with two magnesites, two dolomites, and two specially treated dolomites. The magnesites (A and B) were from Washington and Canada respectively, each being ground with ferric oxide and deadburned. C was made by coating dolomite grains with basic open-hearth slag at a high temperature. D was made by calcining at a high temperature a mixture of dolomite and iron oxide. E was a calcined dolomite, relatively impure, and F was a rather pure calcined dolomite. Analyses of these materials are given. It was found that the tendency to slaking increased with the lime content, and in the dolomites it varied inversely with the sum of iron oxide, silica and alumina.

Silica bricks are not uncommonly used in contact with magnesia bricks above the slag line of the open hearth, but a buffer layer of chrome bricks is desirable. In all other cases basic materials are generally separated from silica and clay bricks in furnace practice. It was shown that firebricks and silica bricks are capable of acting on magnesite.

In tests for resistance to the corrosive action of a mixture of iron phosphide and ferric oxide, it was found that the materials lowest in lime offered most resistance; C showed slightly less resistance than E, and D was decidedly inferior to E and F.

The two magnesites were subjected to some further tests, including load tests, fusion tests, etc. The magnesites were more resistant than dolomites or dolomitic preparations to slaking, and also to the corrosive action of the phosphide mixture and that of fireclay and silica. The mixture C had so slight a tendency to slake that it could be grouped with the magnesites as regards that property; in resistance to corrosion C resembled more closely the untreated calcined dolomite high in impurities (E).

Having regard only to these tests, the value for refractory purposes of the materials studied may be placed in order thus: A (magnesite low in lime); B (magnesite high in lime); C (a treated dolomite); E (a calcined dolomite high in impurities); D (a treated dolomite); F (a pure calcined dolomite low in impurities).

FINE CRUSHING IN BALL MILLS.—E. W. Davis (*Trans. Amer. Inst. Min. Eng. Bull.*, No. 146, 111, 1919). In this article of 46 pages, the subject matter is arranged under four main headings and 26 sub-headings. The main headings are: I. Operating Tests. II. Mechanics of the Ball Mill. III. Ball Wear; and IV. Practical Application of Theoretical Conclusions. It is only the last of these which is not subdivided.

I. *Operating Tests* are considered under the sub-headings: (1) Character of Ore under Investigation, (2) Equipment of the Testing Plant, (3) Open-circuit Crushing, (4) Closed-circuit Crushing, (5) Single-stage Crushing, (6) Two-stage Crushing, (7) Large *vs.* Small Balls, (8) Relation between Speed of Mill and Size of Balls, (9) Deductions from Operating Tests, and (10) Design and Regulation of Fine-crushing Plant.

II. *Mechanics of the Ball Mill* comprises: (11) Action of Charge at Low Speed, (12) Action of Charge at Higher Speeds, (13) Parabolic Paths of the Falling Particles, (14) Application to a Definite Problem, (15) The End of the Parabolic Path, (16) The Blow Struck by the Falling Particle, (17) The Cycle of the Charge, (18) Volume of the Charge, (19) Power, (20) Consideration of a Definite Case, (21) Summary of Ball Mill Mechanics, (22) Comparison of Observed and Calculated Curves, (23) Conclusions as to Ball Mill Operation.

III. *Ball Wear* comprises: (24) Data on Ball Charges, (25) Conclusions as to Ball Wear, (26) Recapitulation of Ball Wear Formulas.

1. *Character of Ore under Investigation.* This was a silicious rock containing bands and fine grains of magnetite, the latter forming about 35 per cent. of the rock, whilst the rest was chiefly quartzite and iron silicates. The rock has a specific gravity of 3·4, a hardness of 7, and it is very tough. The difficulty and expense of concentration of the iron in this rock has prevented it being utilized in the Minnesota iron-ore industry, owing to the proximity of richer ores. The magnetite is finely disseminated throughout, and there are bands or lenses of material of higher and of lower grade, in which the magnetite and silicate are intimately mixed. It is necessary to crush to 200 mesh to get the desired product, and fine crushing is one of the most expensive items, so it has been studied in detail.

Previous to fine crushing, the portions of rock with little or no magnetite can be discarded by magnetic concentrators after each reduction in size in the dry-crushing plant. In this way a minimum of rock is fine-crushed, and the feed to the ball mill is kept below $\frac{1}{4}$ inch. The fine-crushing problem then consists simply in crushing the rock from $\frac{1}{4}$ inch to 200 mesh at minimum expense.

2. *Equipment.* The fine-crushing plant contains a Hardinge 8 feet by 22 inch conical mill, a 6 feet by 27 feet Dorr duplex bowl-type classifier, a $4\frac{1}{2}$ feet standard Akins classifier, and the necessary auxiliary machinery for handling the products. Water is metered in, and every precaution taken to make the

data reliable. Comparisons have been made on the basis of kilowatt-hours per ton of material finer than 200 mesh actually produced.

3. *Open-circuit Crushing.* The tonnage of finer than 200-mesh material produced varied directly with the tonnage fed to the mill, no limit to this relation being indicated at 18 tons per hour. It was concluded that the ball mill is naturally a machine of very large capacity, and that if it is not possible to deliver a large tonnage of original feed to the mill a closed circuit should be provided so that the mill may crush its own oversize.

4. *Closed-circuit Crushing.* General results similar to open-circuit, and no indication of change at 16 tons per hour. In both cases also the power per ton continually decreased as tons per hour original feed increased. The two curves slowly converged, and the real advantage of the closed-circuit system lies in the much greater uniformity in size of particles produced, though the average reduction may be the same in both systems. It is concluded that, for equal tonnages of original feed, (*a*) the closed-circuit crushing system produces the greater tonnage per kilowatt-hour of material finer than 200-mesh, and (*b*) the closed-circuit system also shows the greater average reduction; (*c*) the mill was not operated at or near a tonnage that would give the greatest number of tons per kilowatt-hour of material finer than 200-mesh; (*d*) the maximum size particle produced will always be much nearer the average size in closed-circuit crushing than in open-circuit crushing—a desirable condition since the size of the balls making up the charge must be computed on the maximum size particles in the feed rather than the average size.

5 and 6. From data obtained in *single-stage and two-stage crushing*, it is concluded that two-stage crushing is more efficient than single-stage, and that it is also much more flexible and offers greater possibilities for improvement; in addition, a considerable amount of tailing can be discarded between the stages.

7. *Small balls* produced a much more uniform sand than the large balls did. Large balls seemed to reduce the coarse particles very readily but not the finer particles, whereas the small balls seem to crush all particles equally well. The best results were obtained when the screen analysis of the sands is about uniform between the size of the original feed and the size of the overflow. If the screen analysis of the sands is crowded on the upper end, the balls are too small; if it is crowded at the approximate size of the overflow, the balls are too large.

8. *Relation between Speed of Mill and Size of Balls.* It is concluded from the data that with large balls, or high speed of the mill, crowding will appear at the finer sizes in the classifier sands, and conversely, with small balls or low speed, crowding will appear at the coarser sizes in the classifier sands. It also seems—though this is not definitely proved—that greatest efficiency is obtained when the screen analysis of the sands shows a minimum of crowding at any size.

9. *Deductions from Operating Tests.* The following general conclusions were drawn from more than 150 tests, of which the foregoing included only a few of the more important ones. (*a*) In every case increase in the tonnage fed to the mill resulted in increased efficiency. (*b*) In every test the limiting factor of the test was not the ball mill but some auxiliary apparatus, usually the classifier. (*c*) All tests indicate that the ball mill is a machine of very large capacity, especially when provided with proper auxiliary apparatus. (*d*) Classifying and pulp-handling machines that will handle a circulating load of at least 500 per cent. of the original feed should be provided. (*e*) Closed-circuit crushing is more desirable than open-circuit. (*f*) The real advantage in closed-circuit crushing is that the maximum size of particle is nearer the average size of particle discharged from the circuit. (*g*) Two-stage crushing is more efficient than single-stage. (*h*) The real advantage in two-stage crushing is that the ball charges can be adjusted more nearly to the required conditions (*i*) Two-stage open-circuit crushing does not present this advantage, as the maximum-sized particle in both stages is more nearly the same. (*k*) The proper adjustment between size of balls and speed of mill can

be secured by an examination of the classifier sands. (*l*) If the balls are large or the speed is high, the screen analysis of classifier sands will be crowded at the finer sizes. (*m*) If the balls are small, or the speed is low, the screen analysis of the classifier sands will be crowded at the coarser sizes. (*n*) The greatest efficiency seems to be obtained when the screen analysis of the classifier sands show a minimum of crowding at any size. (*o*) Balls no larger than necessary should be used, as this makes it possible to charge the mill with the greatest number of balls. (*p*) Balls smaller than can crush the larger particles of ore should not be kept in the mill, as they take up space, absorb power, and do inefficient crushing.

10. *Design and Regulation of a Fine Crushing Plant* is discussed on the basis of the foregoing conclusions and the available data. A flow sheet is figured to illustrate the requirements showing a plant with an estimated capacity of 720 tons per day (original feed). It would require 344 kw. at the switchboard, equivalent to 11·5 kw.-hr. per ton of ore crushed, or 14 kw.-hr. per ton of material finer than 200-mesh actually reduced. Better results were often obtained in the tests. Of the 720 tons per day, or 30 tons per hour, of original feed, each of the two first-stage ball mills will crush 15 tons per hour to finer than 48-mesh. This 15 tons will pass into the Simplex bowl-type classifier, where 10 tons will overflow as finished product; the 5 tons of sand from each Simplex classifier will constitute the feed to the second-stage ball mill. This can be accomplished with one (Duplex) classifier in closed circuit with each ball mill, but, by adding a second classifier to each, it is expected that the tonnage can be increased at least 25 per cent. To maintain this feed rate, the proper ball charge must be maintained in each mill, as a slight increase or decrease in average size of the balls making up the charge will cause great loss in efficiency and reduction in tonnage. If balls 3 inches in diameter are fed to the first-stage mills, and all less than 2 inches are removed regularly, the average size of the balls forming the working charge will be 2½ inches, which is about the size indicated in the tests as giving the best results. It is calculated that 249 three-inch balls would need to be charged into each first-stage mill per day, and that 1,743 balls of diameter between 2 inches and 1·92 inch (of total weight 1,995 lb.) would have to be removed from each during a weekly stoppage of the mills. These small balls would be used up in the second-stage mill, to which 498 of them (weighing 571 lb.) should be added each day. At regular intervals all balls less than 1 inch in diameter should be removed from this mill. The foregoing calculations are on the assumption that the ball wear is 2 lb. per ton. The screening of the ball charge in the second-stage mill may be done once a month.

The chief advantages in this flow sheet are: good efficiency as to power expended, large tonnage for the capital invested, and flexibility. By adjusting the overflow end of the classifier in the first stage the load can be balanced perfectly between the two crushing stages.

II. *Mechanics of the Ball Mill.* This comprises a detailed mathematical investigation of the subject. Under sub-heading 21 (Summary of Ball Mill Mechanics) is collected a number of general equations and equations showing relations when operating at best theoretical efficiency. By use of these equations, with any given set of conditions, it is possible to determine the geometrical shape of the charge in the mill, the horse power absorbed by it, the velocity of the blow struck by any ball, and the number of blows struck by any ball. The equations show also the relations that should exist between speed, diameter of mill and size of charge in order to secure the maximum theoretical efficiency. Under sub-heading 22 (Comparison of Observed and Calculated Curves) it is shown how closely the observed results agree with the theoretical calculations in the case of a small model mill. Under sub-heading 23 (Conclusions as to Ball Mill Operation) the following are stated: By the use of two formulas, the proper theoretical speed for the operation of the mill may be computed, but this speed is correct only when there is no slipping between the charge and the lining of the mill, and when the pulp is not so thick as to produce strong adhesion between the particles. In actual practice

it may be found that more effective crushing can be done at some other speed, but apparently the variation above or below this theoretical speed should be small. When operating at the speed shown by formula 13, the crushing is largely done by impact. [Formula or equation 13 is $N = 48{\cdot}95 / \sqrt{r_1} \sqrt[4]{1+K^2}$, where N = speed of mill in rev. per min., r_1 = radius of mill, K = a constant = r_2/r_1, r_2 being inner radius of charge.] At speeds lower than N (equation 13) the proportion of the crushing done by attrition is increased, and at speeds higher than N the proportion of crushing done by impact is increased. The amount of crushing done depends on the number of blows struck and the work done at each blow. The number of blows struck can be increased by increasing the number and decreasing the size of the balls. The work done at each blow can be increased by increasing the weight of the ball and by increasing the diameter of the mill. Hence mills of larger diameter should be charged with smaller balls and mills of smaller diameter with larger balls, when working on the same feed. The proper operating speeds of ball mills vary inversely as the square-roots of the diameters, and increase as the size of the ball load increases. Owing to interference between the balls the volume of the charge should not be over 60 per cent. of the volume of the mill. Unless great care is exercised to prevent slippage, the volume of the ball charge should not be less than 20 per cent. of the volume of the mill. A ball charge that occupies between 25 and 50 per cent. of the volume of the mill will apparently then give the most satisfactory results. In an 8 feet mill running at 22 r.p.m., with a 28,000 lb. charge of 2-inch balls, there will be an average of about 1,000,000 blows per minute, each blow equivalent to dropping a 2-inch ball 5 feet.

III. *Ball Wear* is discussed theoretically, and some data and formulas are given. The following conclusions were drawn: In any mill, the rate at which the weight or diameter of any ball decreases is directly proportional to its weight or diameter respectively, and similarly with regard to the surface of any ball. As the rate at which a ball loses weight varies as the work done upon it in the mill, the work done in wearing (or crushing) the ball varies as the weight of the ball—Kick's law thus holding true for the ball wear in a rotating mill. The natural tendency is for the small balls to accumulate in the mill charge, and since these small balls do very little crushing, and exclude ore and larger balls from the mill, a marked decrease in crushing efficiency will result from their accumulation (if left too long). For the greatest efficiency, the balls should be of practically uniform size. Since spheres of uniform size provide the greatest amount of interstitial space, a mill charge composed of balls of uniform size will allow freer migration of the ore particles than a charge containing balls of different sizes.

IV. *Practical Application of Theoretical Conclusions.* Though the proper mill speed can be calculated for any definite volume of charge, the size of the balls must be determined experimentally. The proper mill speed and the volume of the charge depend almost entirely on the size of the mill, and perhaps a little on its characteristics, but not on whether the ore is hard or soft, coarse or fine. The size of balls is a most important factor in crushing, and each different condition requires balls of a different size. The following method is recommended as a good means for determining the exact size of the balls that should be used. The mill is charged with balls that are too large, say 5 inches in diameter, an ammeter or wattmeter being connected in the circuit of the driving motor so that the operator may keep the ball load constant by observing the power required by the mill. For maintaining this constant ball load, only balls of the same size as those already in the mill are added—that is, a different size is added each time according to the amount of wear. By keeping the records of each day's run, the operator can determine which size produced the best result under the conditions. The ball charge should then be composed of balls as near this size as is practical and economical.

The proper size of balls to be added at the end of each 24 hour period can be determined by computations, or by sampling the ball charge and actually measuring the balls; in some mills a sampler can be inserted through the discharge trunnion for this purpose.

It is hoped that makers of ball mills will succeed in producing a mill that will automatically discard balls as they become worn down to a given diameter.

Large circulating loads—as already pointed out—seem essential for the greatest efficiency. Classification is cheap compared with fine crushing, and a classification capacity exceeding the capacity of the ball mill is very desirable.

III.—THE COMPOUNDING & PREPARATION OF CLAYS AND BODIES.

IRON SEPARATORS IN THE MILLING OF MINERALS.—K.W. (*Tonwar. Ofen. Ztg.*, **41**, 45, 64, 1917). A brief review of the contrivances employed (permanent magnets and electro-magnets).

REFRACTORY BRICKS.—L. (*Chem. Appar.*, **4**, 21, 1917). In most cases for production of refractory bricks (especially for strong resistance to chemical influences) are used shale, raw kaolin and sandy clays, quartz rock, grog, etc., to which coke, wood charcoal, bauxite, magnesia, etc., may be added. For electric furnaces the bricks are produced from a mixture of foundry coke with low ash content and coal tar. These bricks are pressed, dried and then burned in muffles. These carbon bricks are very hard, but still always porous and possess a somewhat close texture. Such bricks can now be made in simple fashion according to a process of K. Albert and L. Berend (German patent 294,661) by mixing ground coke with watery emulsions of mineral bodies like tar, pitch, tar oil, asphalt, fat oils, etc., which contain an organic substance from which a carbon is formed, the mixture is pressed, and coked in a closed kiln. Such watery emulsions are easily produced with the aid of molasses, starch paste, glue, sugar and similar substances, and a particularly fine carbon brick should be obtained if thickened sulphite waste liquor be employed. In this way also earthenware bodies of the most varied kinds, clays, kaolin, magnesia, etc., mixed with such emulsions can be burned and composite carbon brick bodies produced thereby, and (except for acid-proof and fireproof bricks) the bodies can also be burned to tubes, pipes, and vessels of every kind for the chemical industry. The articles are very valuable on account of their chemical indifference. Additions of every kind can be added to the earthenware masses, as well as to the emulsions.

CHEMICAL PORCELAIN.—C. F. Binns (*Brick Pot. Tr. J.*, **25**, 171, 1917) Abstract of paper read before the N.Y. Sections of the American Electrochemical Society, American Chemical Society, and Society of Chemical Industry. The body and glaze contain the same oxides, silica, alumina, lime, and potash. Nothing else is essential, and almost everything else is detrimental. In modern practice the pot is fired to about 1,000° C. to facilitate handling. It is then dipped in glaze, and body and glaze are matured together by the finishing fire (about 1,430° C). A low temperature is necessary for the first burning, because if the ferric oxide in the clay should be enclosed in non-permeable material the subsequent reducing fire could not change the yellow tone to the necessary blue. Iron, even to the amount of 1 per cent., need not be objectionable in the clays used. Kaolins are usually rather coarse in grain and have low plasticity, so a more plastic clay is sometimes added to the mixture. It is a curious fact that soda felspar, when used as a flux instead of potash felspar, gives vitrified and translucent porcelain, but such ware when struck sounds dead. Besides clay and felspar, the mixture contains a little quartz, and generally 2 or 3 per cent. of calcium carbonate; this last is not invariably present, but it improves the colour, promotes vitrification and increases the strength of the ware.

The American plan for clay mixing is to feed the whole charge of weighed material into a blunger. The thin liquid is sieved through wire sieves or silk lawn of 100 or 120 meshes to the linear inch. In England the prevailing custom

is to grind each non-plastic substance separately in water and to blunge the clays separately, the mixing being done by measure after adjusting the pint-weights of the several materials. Continental potters usually weigh the batch and grind it. In Germany either the whole batch is ground in a cylinder or the quartz and felspar are ground and mixed with the previously blunged and screened clay.

The clay body is shaped (1) on the potter's wheel by hand, (2) in plaster moulds, (3) by pressing as moist dust in steel moulds, and (4) by casting in porous moulds (usually plaster).

The best chemical porcelains (equal to the German porcelains in behaviour) contain about 80 per cent. clay, 10 per cent. felspar, and 10 per cent. quartz. A glaze for chemical porcelain, to mature at about 1,450° C., should correspond to $0{\cdot}3K_2O$, $0{\cdot}7CaO$, $0{\cdot}9Al_2O_3$, $9{\cdot}0SiO_2$, and may be made from 22 parts felspar, 9 whiting, 21 clay and 48 quartz. The corresponding percentages are 78 silica, 12 alumina, 6 lime, and 4 potash. This glaze also proved fully equal to the German glaze in laboratory tests. The best wares (Berlin, Bavarian, Copenhagen, Meissen) stand very severe tests.

STONEWARE PIPES.—(*Brick Pot. Tr. J.*, **25**, 267, 1917). A discussion of the troubles arising in the making processes, with suggested precautions for avoiding them.

PREPARING AND WEATHERING CLAYS.—(*Brick Pot. Tr. J.*, **25**, 277, 1917). A general discussion of the factors concerned in preparing clays and shales for use. Taken from *Brick*.

MINERAL WOOL FROM BASALT.—(*Quarry*, **22**, 129, 1917). A note from the *Melbourne Age* through the *Board of Trade Journal*. Pure white soft mineral wool is being manufactured on the outskirts of Melbourne, from basalt or "bluestone." It is used for engine packing, and in several ways as a substitute for asbestos. The shortness of the staple (about 1½ to 2 in.) prevents it being used for weaving, but there is increasing demand as an insulator, etc.

ELECTRO-TECHNICAL PORCELAIN.—(*Quarry*, **22**, 88, 1917). Has reference to certain French products, and is taken from *Rivista Tecnica d'Elettricita*, Feb. 22nd, 1917. White clays have two different physical aspects, true clays with opaque fracture, and halloysite with transparent fracture. The first are simply mixed with water, whereas the second must be ground previously. In a porcelain body before firing, both kinds act as binding materials. But objects made of clay alone would not dry properly owing to cracks being formed, they would undergo excessive shrinkage in firing (about 22 per cent.), and they would have to be fired to an extremely high temperature to make the clay permeable and insulating. The addition of silica or felspar would obviate drying troubles, silica would limit the shrinkage in firing, and addition of felspar to clay and silica would give a convenient firing temperature. Silica and felspar are sometimes added together in the form of pegmatite. The most fusible mixture of clay and silica melts at 1,600° C.

For a suitable body experience shows that 40 per cent. is a minimum for clay (theoretically pure). The medium amount of alkali for French and other bodies is 5 per cent. K_2O or the equivalent amount of Na_2O, which in the case of potash would need 34 per cent. of pure orthoclase (potash felspar), the balance being made up with 26 per cent. silica. As perfectly pure mineral substances are rarely obtainable in quantity, allowance must be made for variations in composition.

Fired porcelain bodies have different aspects according to the manufacturer's formula, not (as commonly supposed) according to the grinding and firing. With the same insulating power, the fracture of an alkaline-silica body, even with excessive grinding and firing, will always be granular, like refined sugar, whereas an alkaline alumina body will always be silky, as in sugar candy. Lime and magnesia in small quantities are often added to bodies.

The glaze for the porcelain contains the same ingredients as the glaze, but with the felspar in larger proportion to give transparency. This glaze is

more durable than bottle glass (commonly employed for making insulators). The following analyses illustrate differences between glaze and glasses :—

	Silica	Alumina	Iron Oxide	Lime	Magnesia	Potash	Soda	Total
Porcelain enamels	80·80	10·80	—	1·68	—	3·95	2·86	100·00
Opaque glass ...	62·30	4·30	2·20	18·50	4·80	2·50	5·77	100·00
,, ,, ...	61·80	4·56	1·74	19·66	5·44	0·80	6·00	100·00
Clear glass ...	64·63	1·84	1·05	20·60	5·60	0·58	5·70	100·00

The greater the proportion of fusible constituents in glass, the more readily it melts, but it also becomes softer and more readily attacked by external agents.

" BLIBS " IN EARTHENWARE.—A. G. Richardson (*Pot. Gaz.*, **42**, 39, 1917). Relates to occurrences in ware made from alkaline casting slip. See also Trans., **17**, 208, 1918.

BOWING OF TILES.—T. A. Simpson (*Pot. Gaz.*, **42**, 41, 1917). See also Trans., **17**, 206, 1918.

CHINA SLIP FOR CASTING.—A. Heath (*Pot. Gaz.*, **42**, 41, 1917). See also Trans., **17**, 206, 1918.

FLOW OF CLAY THROUGH HOLLOWWARE DIES.—G. D. Morris (*Brick*, **51**, 778, 1917). Reprinted from *Trans. Amer. Cer. Soc.*, **19**, 479, 1917.

CASTING OF HEAVY CLAYWARE.—F. H. Riddle (*Brick*, **51**, 1,129, 1917). Refers more particularly to the casting of open top glass pots with heavy walls.

BRICKS OF CEMENT AND BURNED CLAY.—(*Brick*, **51**, 673, 1917). Has reference to bricks made by machinery from a mixture of cement and calcined clay, the latter being graded (dust up to half-inch).

PREPARING AND WEATHERING CLAYS.—(*Brick*, **51**, 594, 1917). A brief discussion of the advantages to be derived from careful preparation, including drying when necessary.

PREPARATION OF CRUCIBLE GRAPHITE.—G. D. Dub (*War Minerals Investigation Series* No. 3, *U.S. Bureau of Mines*, 1918). A description (illustrated) of the methods of mining, concentrating, and refining graphite, and a suggested standard method of sampling finished graphite, with tentative specifications, methods of analysis, etc.

The principal producing states are Alabama, New York, Pennsylvania, and Texas. Graphite is also refined from " kish," a by-product from iron blast furnace and steel plants.

Among the methods of concentration described is the water " skin-flotation " system, with three types of washers (Munro, Colmer, and New Munro).

STORING, ANNEALING, AND HANDLING PLUMBAGO OR GRAPHITE CRUCIBLES.—A. Phipps (*Metal Industry*, **14**, 481, 1919). Plumbago or graphite crucibles readily absorb atmospheric moisture, and may contain a considerable amount when received at the foundry. Hence crucibles should always be stored in a warm dry place. For small crucibles, say 40 to 100 lb. capacity, a temperature of 200° for 48 hours is sufficient to drive off excess of moisture, whilst for 120 to 250 lb. capacity at least 70 hours is necessary, and for 300 to 1,000 lb. not less than 100 hours in the stove. An extension of the times named would be better, but the temperature should not be exceeded. The stove should be properly ventilated.

The crucible should not (as is commonly done) be placed immediately upon the hot flue plates running behind the furnaces, but on shallow sheet iron trays containing about two inches of sharp, dry sand. The crucibles should be placed bottom upwards, so that the thinner parts receive most heat at first.

The annealing period need not exceed 12 to 60 hours, according to size of crucibles. Precautions necessary in moving crucibles in or out of the furnace are also described. The tongs should grip the crucible all round.

FURNACE SLAG AS GROG IN ARCHITECTURAL TERRA-COTTA BODIES.—R. H. Minton (*J. Amer. Cer. Soc.*, **1**, 185, 1918). With reference to dunting of architectural terra-cotta, E. C. Hill states, in hitherto unpublished report of an investigation, that " fire cracking seems to depend almost entirely on two factors, namely, the composition of the body and the rate and method of cooling. Regarding the composition, it was noted that bodies composed of very sandy clays are much more sensitive to fire cracking than those made of less sandy, more plastic clays." His final conclusion was that " while cooling is of the greatest importance, the composition and density of the body are large factors in the sensitiveness of the body to fire cracking."

The author agrees with Hill's view that the body should be controlled by the size and the amount of the grog rather than by the use of sandy clays, but contends that the kind of grog is equally important.

Promising results have been obtained by the use of acid slag, the basic slags being unsatisfactory as grog owing to their high specific gravity and their high content of lime. It is concluded that if further experiments confirm the practicability of using slag as grog in architectural terra-cotta, a lighter material than saggar grog will be available at less than half the cost of the latter.

Hill's paper on the " Theory of Dunting " is appended.

NEWCOMB POTTERY.—M. G. Scheerer and P. E. Cox (*J. Amer. Cer. Soc.*, **1**, 518, 1918). Historical and descriptive account of an out-of-the-way art pottery near New Orleans, with particulars relating to body, glaze, decoration, kilns, saggars, etc.

NATURE OF THE AIR CONTENT OF PUGGED CLAYS.—H. Spurrier (*J. Amer. Cer. Soc.*, **1**, 584, 1918). Air from pugged clay was analysed, and found to consist of 3·85 per cent. carbon dioxide, 13·46 oxygen, 1·92 carbon monoxide, and 80·77 nitrogen.

DETERMINATION OF AIR IN PLASTIC CLAY.—H. Spurrier (*J. Amer. Cer. Soc.*, **1**, 710, 1918). The manner in which a piece of clay slakes down in water indicates the method of its formation. In a piece made on a special extrusion machine, the separation of the clay particles takes place along longitudinal lines, indicating that the air cavities lie along parallel planes. Thrown pieces show plainly the spiral striæ formed in throwing. A piece cut from a filter-press roll does not slake or disintegrate in boiling water, but may remain indefinitely in the water without slaking down. This latter case shows clearly that it is the disruptive effect of the expanding gas vesicles that causes the clay to slake down. Kerosene was found to have no tendency to slake the clay or otherwise disturb it, and it does not dissolve the air.

A method is described for determining the amount of air, and is available for use with pugged clay so as to determine the proper blade setting of pug mills.

SOME TYPES OF PORCELAIN.—F. H. Riddle and W. W. McDanel (*J. Amer. Cer. Soc.*, **1**, 606, 1918). Has reference to porcelain bodies fired at temperatures not below the softening point of cone 10—including electrical porcelain, most hotel china, chemical porcelain, etc. In Europe the ware is fired first at a low temperature, and the body is matured by the glost firing. In America the body is matured by the biscuit firing, and, after glazing, the ware is subjected to a lower temperature for the glost firing.

The chief purpose of this study was to determine the firing range of such porcelain bodies, the clay content of which varied from 45 to 85 per cent., and the felspar from 10 to 30 per cent. With 45 and 50 per cent. clay, the felspar was 16 to 30 per cent., the remainder being flint; mixtures with 55 per cent. of clay and more contained 1·5 per cent. whiting. With 55 and 60 per cent.

clay the felspar was 14·5 to 28·5, the remainder being flint; with 70, 75, 80, and 85 per cent. clay, the felspar was 10 to 28·5, 10 to 23·5, 10 to 18·5, and 13·5 per cent. respectively, the 100 being made up (when necessary) with flint. Where the clay content was over 55 per cent. the excess was calcined to cone 14 and ground dry to pass a 120-mesh sieve.

The results are shown in tables and by means of plotted curves. The porosity-temperature and the volume-temperature relations are very significant in studying the burning range and behaviour of a body. Zero porosity or (better) zero absorption may be considered the first point of maturity. A more sensitive criterion of maturity is the point of greatest density or smallest volume, which should correspond to the most suitable firing temperature. As soon as overburning starts—owing to development of vesicular structure—the volume increases. The greater the temperature difference between the point of zero porosity and that at which overburning is evident, the wider is the firing range of a body.

The firing ranges of high felspar and low felspar bodies are nearly the same, but the maturing temperatures are much lower for the high felspar bodies. Variation in the content of flux has a more marked effect on the low clay than on the high clay bodies. But the difference in the burning ranges of bodies with constant flux but varying clay (and flint) is rather small). Ball clay increases the tendency of the body to overburn, and tends also to close the body up (and mature) at lower temperatures. Aged bodies without ball clay shrink less than similar fresh bodies. Ball clay tends to shorten the firing range, and when used it should be in as small amount as possible.

The presence of small proportions of lime and magnesia produces a decided effect. Lime does not hasten the maturing of the body but causes overburning at a lower temperature, thus shortening the firing range. Magnesia, or a mixture of magnesia and lime, causes the body to mature much earlier, and brings about the overfired state at a lower temperature.

Baryta seems to render no useful service in such bodies. Volume shrinkage is greater with addition of magnesia (or magnesia and lime) than with addition of lime or baryta.

The addition of small amounts of magnesite or dolomite is beneficial in many ways, particularly to bodies which should mature at cone 10 to cone 11.

A special body containing artificial sillimanite (prepared from kaolin and alumina), instead of quartz or flint, had a long temperature range. As the sillimanite bodies have a low coefficient of expansion, it is suggested that if abundant natural deposits of the mineral could be found, the material could be used with advantage.

The range of composition of bodies to be fired at cones 10 to 12 is given, including 3 to 8 per cent. ball clay, and 4·0 to 0·5 per cent. of alkaline earth fluxes. The lime, magnesia, or dolomite fluxes are helpful in giving a white colour. Dolomite occurs pure enough for use in pottery bodies.

The colour of white wares is discussed, including an indication of the best mode of procedure for European hard porcelain.

MAGNESIA WARE.—T. D. Yensen (*J. Amer. Cer. Soc.*, **1**, 730, 1918). The author states that magnesia was fused at the University of Wisconsin and the fused product crushed and made into magnesia crucibles before 1910, and this has been continued there since. The author has himself made magnesia crucibles for laboratory purposes almost without interruption since 1912, and the method used was first published in 1914.

Calcined magnesite was fused in an electric arc furnace, the fused magnesia crushed to pass a 40-mesh screen, then mixed with about 5 per cent. hydrated magnesia, moulded into crucibles in a steel mould, dried, and finally heated to 1,800° C. in an electric furnace. These crucibles were uniform, strong, had little shrinkage, and showed no sign of softening at 1,800° C.

Magnesia containers are the best for melting pure iron and iron alloys.

Large crystals separated from fused magnesia were found to be cubical and isotropic, and to have very high refractive index and low dispersion—properties valuable in a material for making lenses.

FELSPARS IN PORCELAIN BODIES.—(*Sprech.*, **51**, 56, 1918). Taken from paper by A. S. Watts on the use of mixtures of potash and soda felspars, in *Trans. Amer. Cer. Soc.*, **16**, 212, 1914.

PRODUCTION OF SAGGAR BODIES.—A. Heinecke (*Sprech.*, **51**, 233, 1918). An address to the Technical Section of the Association of Ceramic Works in Germany. A review of the processes in the preparation. The use of clay or kaolin in coarse pieces is condemned, and previous grinding of the clay recommended to give a better chance for the clay to envelop the grog particles. Still better is it to mix the substances dry, a plan long followed with success at several *Schamotte* factories. With the use of several plastic substances as binding materials this method of working allows a really intimate mixture to be obtained. This process can be worked in a similar manner as in the production of a fine ceramic body, and has been proved advantageous—the materials being simultaneously passed through suitable sieves, and then well mixed in a mixing machine, from which the mixture is passed into a moistening contrivance. The grog particles should be free from dust. Further details are given.

IS BLAST FURNACE SLAG A FLUX IN THE PRODUCTION OF CLAY SLABS?—E. Bkg (*Ker. Rund.*, **26**, 27, 1918). The clay slabs, consisting of Eifel clay and blast furnace slag (the latter having a melting point above cone 9), like those from works in France, Germany, etc., are fired at a temperature not exceeding cone 1a, which is too low for either the alkalies and alkaline earths in the slag or in the clay to act as flux. The average composition of the clay used shows 58·63 silica, 28·27 alumina, 0·97 ferric oxide, 1·26 alkalies, 10·50 loss on ignition, with a little lime and magnesia. Granger and others have attributed a fluxing action to the slag, but, as the author points out, it is to be considered rather as a non-plastic ingredient.

CLAY COOKING VESSELS.—K. Ernst (*Ker. Rund.*, **26**, 45, 1918). In the case of ordinary clay products the body owes its property of withstanding a weak hearth fire to its porosity, which is determined by its richness in sand, but extremely careful working is necessary throughout in order to get satisfactory products. As obtained, most of the clay is not of use for production of cooking vessels, but needs more or less preparation. Often drying, grinding, and sieving are sufficient, but in many cases it is necessary to wash the clay; for this it is sufficient to let the clay slime run over a drum sieve, which keeps back the coarser impurities, but lets through the sand as far as is necessary for the prepared body. If the clay does not contain enough sand, an addition of sand or grog dust must be made; it is advisable to leave the mixture in a cellar, as the later working is thereby facilitated. In shaping, great care is needed to ensure uniform thickness, as otherwise the pieces will be very liable to crack on heating. When an engobe is applied to the inside of a vessel, it is advisable to add it when the body is in leather hard condition. The production of a suitable engobe is one of the most difficult problems in the production of cooking vessels.

As glazes, either leadless glazes or earthenware glazes poor in lead are most suitable. They need not be free from crazing, for glazes which craze offer less opposition to the expansion of the body, and so favourably influence the fireproof quality. A wide-meshed network of crazes is to be avoided, as it very often breaks up the engobe and runs into the body. The brown external glaze is mostly obtained by addition of iron oxide to the white glaze. Internal glazing is effected by pouring, and external glazing by dipping up to the rim. The first firing is mostly taken up only to cone 05a, and the second fire up to cone 02a—2a, as it is not easy to prepare leadless glazes at lower temperatures. Earthenware ovens are generally used, with similar saggars, but a two stage oven is to be recommended for burning biscuit and glost at the same time.

SAGGAR BODIES.—A. Heinecke (*Ker. Rund.*, **26**, 235, 1918). See abstract from *Sprech.*, **51**, 233, 1918.

GLAZED CERAMIC WARES.—C. Stegmayer, U.S. Pat. 1,245,285, Nov. 6th, 1917. Relates to articles made from a body consisting of ordinary clay mixed with a powdered flux, an engobe consisting of vitrifiable porcelain in powder, and a leadless glaze also in powder. The body, engobe, and glaze are arranged in three layers, which are subjected to compression and afterwards exposed to a single firing.

REFRACTORY MATERIAL FROM DOLOMITE.—J. O. Handy and R. M. Isham, U.S. Pat. 1,248,486, Dec. 4th, 1917. Deadburned dolomite is mixed with a temporary binder, moulded into bricks, and fired at a high temperature until sintered. The product is resistant to boiling water.

BRICKS, etc.—H. W. Charlton, U.S. Pat. 1,249,028, Dec. 4th, 1917. See Eng. Pat. 1,540, 1918. Also TRANS., **18**, Abs. 76, 1919.

PURIFYING CLAYS, etc.—F. Langford, U.S. Pats. 1,251,057 and 1,251,058, Dec. 25th, 1917. Ferruginous clays, etc., are washed with a solution containing tannic acid to remove iron compounds, etc. The insoluble residue on treatment with a mineral acid leaves an insoluble residue rich in silica. The second patent relates to treatment of similar materials with hot very dilute sulphuric acid (with less than 1 per cent. of acid), which dissolves iron compounds and impurities with a minimum action on aluminium compounds.

SILICIOUS FIREBRICKS.—H. A. Kennedy, U.S. Pat. 1,260,398, March 26th, 1918. Silica in particles of substantial size and free from fine silica powder or sand is mixed with a binder (such as fireclay) and made into bricks.

INSULATING (PORCELAIN) BODY.—A. Champion and T. G. McDougal, U.S. Pat. 1,262,305, April 9th, 1918. Relates to insulating material for sparking plugs, calcined clay being used as one of the non-plastic ingredients. A mixture is specified consisting of 60 plastic clay, 10 felspar, and 30 calcined clay and flint.

ACID-RESISTING REFRACTORY INSULATING MATERIAL.—H. Stegmeyer, Ger. Pat. 302,834, March 5th, 1915. Articles made from a plastic mixture of water-glass with filling material (porcelain dust, sand, graphite, etc., or several of them), are hardened by heating under pressure in an atmosphere of carbon dioxide or with acid gas or vapour. The product resists concentrated sulphuric acid better than chemical stoneware, and is more resistant to temperature variations than firebricks, etc.

UNFIRED REFRACTORY PRODUCTS.—Ger. Pat. 302,877, July 11th, 1916. Silicious material free from fluxes is mixed with a calcareous binder, and a little grog, and the mixture is hardened by steam under pressure. The resulting refractory ware does not warp or spall under sudden temperature changes, resists furnace gases and vapours, and has a high crushing strength.

MANUFACTURE OF SILICA BRICKS.—H. Le Chatelier and B. Bogitch (*Comptes rend.*, **165**, 742, 1917). The size of grain should not exceed 0·5 cm., and a considerable portion of very fine particles is also necessary in order to accelerate recrystallization of the quartz as tridymite from the viscous magma, especially if the tridymite network is to make the brick stable at 1,700° C. Under normal firing conditions only grains below 0·03 mm. are completely changed, and grains above 0·05 mm. are practically inert as regards transformation, solution and recrystallization extending only to a depth of about 0·01 mm). The use of impalpable quartz instead of fine quartz (particles less than 0·1 mm.) produced a great increase in the mechanical strength at furnace temperatures. Where the quartz is easily transformed, nothing is gained by previous calcination of the raw material. Substitution of two parts of lime by six parts of clay (containing two parts of bases—alumina, iron oxide, and potash) gave inferior results. These bricks differed also in becoming gradually deformed under load at 1,600° C. instead of exhibiting the sudden collapse

characteristic of bricks with lime bond. The conclusion reached was that 75 per cent. coarse quartz with 25 per cent. of impalpable quartz and 2 per cent. of lime gives the best composition.

MANUFACTURE OF SILICA BRICKS.—Philipon (*Comptes rend.*, **165**, 1,002, 1917). Bricks made of quartz in impalpable powder were found to have a crushing strength of 18 kilogs. per sq. cm. when dried, and of 320 kilogs. when fired at 1,300° C. Similar bricks made of quartz grains 0·13 mm. diameter had corresponding crushing strengths of 2 and 16 kilogs. only. The very fine particles always gave strong bricks, whatever the geological history and physical characters of the silica used, the minimum crushing strength being 200 kilogs. per sq. cm., and the expansion of such bricks on firing is negligibly small. The strength of fired bricks increases with the lime up to 1 per cent., remains unchanged between 1 and 2 per cent., and decreases with more than 2 per cent., each 1 per cent. of lime lowering the refractoriness by about 20° C. Bricks made of impalpable quartz powder begin to soften at 800° C., and at 1,300° C. have a crushing strength of 270 kilogs. per sq. cm., whereas bricks with larger grains do not begin to soften below 1,100° C., but at 1,300° C. have crushing strength of only 70 kilogs. For commercial production it was found best to have at least 96 per cent. silica, 30 per cent. in impalpable powder and 70 per cent. in grains 1 to 8 mm. diameter. The lime added was only 0·6 per cent. of the bricks, but 2 per cent. of the flour. They have answered well for lining Siemens-Martin furnaces.

REFRACTORY FURNACE LINING.—S. B. Newberry, U.S. Pat. 1,267,686, May 28th, 1918. Limestone or magnesian limestone is ground and mixed with 2 to 10 per cent. of alumina with ferric oxide, practically free from silica, but able to produce fusible compounds by combination with lime. The mixture is calcined until a dense clinker is produced.

ALUMINOUS ABRASIVES.—T. B. Allen (and Carborundum Co.), U.S. Pats. 1,268,532 and 1,268,533, June 4th, 1918. An aluminous material with 15 per cent. or more of ferric oxide and silica is heated in a reducing atmosphere until melted, and is then left to cool and crystallize. The second patent relates to a crystalline fused aluminous material in which the crystalline alumina exceeds 60 per cent. and the silica, ferric oxide, and titanium oxide together exceed 10 per cent., and most of the crystals are less than 0·01 mm. in diameter.

ALUMINOUS ABRASIVES.—Norton Co., L. E. Saunders, and R. H. White, U.S. Pat. 1,269,222, June 11th, 1918. To the material used for making aluminous abrasives is added a zinc oxygen compound in small quantity to prevent reduction of the alumina by the carbon in the charge.

REFRACTORY MATERIAL.—J. O. Handy and R. M. Isham, U.S. Pats. 1,270,818 and 1,270,819, July 2nd, 1918. Carbonated refractory material (magnesite, etc.) is mixed with a little chloride in solution, dried, and calcined so as to expel the carbon dioxide and most of the chlorine, leaving a product which resists the action of air, steam, and hot water. In the second patent dolomite is calcined, then treated with cold water until the lime is reduced to 3—10 per cent., and finally heated again with a little binding material.

FURNACE LINING.—O. J. T. G. R. Martin, U.S. Pat. 1,271,052, July 2nd, 1918. 15 parts brick clay, 8 parts infusorial earth, 4 parts soapstone, and 6 parts asbestos, are mixed together, and the mixture made plastic by water containing $\frac{1}{4}$ oz. salt per gallon.

REFRACTORY CERAMIC ARTICLE.—A. W. Olver (and Carborundum Co.), U.S. Pat. 1,273,529, July 23rd, 1918. Plastic clay, carborundum and graphite (or other refractory material), water and tar, are worked up into a highly plastic mixture, which is moulded into the desired form.

ARTIFICIAL STONE.—P. M. Sharples (and White Heat Products Co.), U.S. Pat. 1,273,547, July 23rd, 1918. Calcined sand is mixed with disintegrated glass, and the mixture is shaped, pressed, and then heated until the glass melts.

DENTAL FILLING RESEMBLING ENAMEL.—F. Schoenbeck & Co., Ger. Pat. 306,837, Sept. 6th, 1917. The fused product from a mixture of cryolite, silica and lime is powdered, mixed with phosphoric acid containing dissolved aluminium hydroxide, and worked into a plastic mass.

CHEMICAL STONEWARE.—A. Malinovszky (*Chem. Met. Eng.*, **19**, 485, 1918). Chemical stoneware is made either by mixing several clays, or from a low-grade fireclay alone (the ware being then burned at 1,400°—1,500° C.) or mixed with a cheap flux such as a very fusible impure clay, lime, or furnace slag. The mixture should be highly silicious, but with sufficient plasticity for the shaping of large pieces, and it should have a range of from 200° to 300° C. between complete devitrification and deformation. Coarse particles should be removed. Tests for solubility are described, and also the microscopical structure. The chief minerals present are quartz, orthoclase, plagioclase, magnetite, and altered "ferro-magnesia mineral." The ware may be cooled rapidly to the melting point of the eutectic (800°—1,000° C.), but afterwards should be cooled very slowly. For a somewhat fuller abstract see *J. Soc. Chem. Ind.*, **37**, 653A, 1918.

ABRASIVES.—F. M. Becket (and Electrometallurgical Co.), U.S. Pat. 1,279,828, Sept. 24th, 1918. Relates to an abrasive composed of irregular grains (nearly uniform in size of the alloy [a ferro-chrome alloy] described in U.S. Pat. 1,245,552 [Nov. 6th, 1917], and to abrasive wheels, etc., containing bonded grains of the alloy).

A HOME-MADE BRIQUETTE PLANT.—H. M. Balsam (*Gas J.*, **143**, 392, 1918). Relates to the production of coke-dust briquettes with a tar and pitch binder. No steam was available at the gas-works where they were made.

IV.—SHAPING AND MOULDING. DRYING.

SUPPORTS FOR LIFTING PIECES OUT OF MOULDS.—J. Dupagny (*Cer.*, **20**, 187, 1917). Relates to the removal of articles of earthenware or porcelain from the mould. A discussion of the means of avoiding deformation by attention to the shape of the supports. The article is illustrated.

RENOVATING PLASTER MOULDS.—(*Brick Pot. Tr. J.*, **25**, 176, 1917). An illustrated account of Patent No. 104,448, by J. Bentley and B. Bailey.

PLASTER MOULDS.—(*Brick Pot. Tr. J.*, **25**, 179, 1917). A general discussion of the factors affecting durability.

DRYING CLAY.—(*Brick Pot. Tr. J.*, **25**, 220, 1917). An illustrated description of T. M. Stocker's Patent No. 107,866, of Aug. 31st, 1916. See reference in TRANS., **17**, Abs. 2, 1918.

CASTING OF HEAVY CLAYWARE.—F. H. Riddle (*Brick*, **51**, 1,129, 1917). Refers specially to the production of glass pots for optical glass, details being given of moulds and preparation of body mixture, etc. The slip ready for casting contains 22·6 per cent. water, and 77·4 per cent. dry body, the added sodium carbonate and silicate (equal parts) being 0·266 per cent. of the body. Reference is made to the use of a partial vacuum, and to the lining of glass pots with a different material.

OVERCOMING CRACKING IN DRYING CLAY PRODUCTS.—O. L. Helfrich (*Brick*, **51**, 123, 1917). A discussion of the causes of cracking during drying, and appropriate remedies.

EFFECT OF GRAVITATION UPON THE DRYING OF CERAMIC WARE.—E. W. Washburn (*J. Amer. Cer. Soc.*, **1**, 25, 1918). A discussion of certain observations from which it was inferred that gravitation had influenced the removal of moisture from clay placed in a presumably moist atmosphere.

A CONVEYER STOVE ROOM.—C. E. Jackson (*J. Amer. Cer. Soc.*, **1**, 529, 1918). An account of arrangements devised for working in conjunction with a bat-making machine so as to eliminate all attendant labour for a man working a jigger. It is claimed that the contrivance secures also continuity of output, that the jigger-man can devote all his attention to his work, that the drying is more uniform, the ware is of better quality, and that there is less loss in the biscuit ware room, etc.

TERRA-COTTA DRYERS.—E. Lovejoy (*J. Amer. Cer. Soc.*, **1**, 667, 1918). A general discussion of the problem of drying, and of the attempts to solve it.

WHAT DEMANDS DO CERAMIC FACTORIES PUT ON MOULD PLASTER?—E. Cramer (*Sprech.*, **51**, 211, 1918). An address to the Technical Section of the Association of Ceramic Works in Germany. A brief account of the preparation and properties, etc.

WEATHERPROOF SLABS.—J. K. (*Sprech.*, **51**, 243, 1918). A plea for the production of specially weatherproof dry-pressed, single-fired articles, with modern art glazes. The results of certain trials are given, and the formulæ of several glazes. Tin oxide, rutile, zinc oxide, and tungstic, vanadic, and molybdic acids are stated to have yielded specially beautiful glazes, the colour of the body being apparently of no importance. Molybdic acid acts specially in glazes containing cobalt or copper, causing very interesting separations with strong lustre.

Some of the trials were made at cone 08—07. Promising trials were also made at cone 8—9.

PREVENTING DISTORTION OF CAST PORCELAIN FIGURES, etc.—L. Wunder (*Ker. Rund.*, **26**, 127, 131, 1918). With reference to the purification casting (after long standing of moulds) to remove adhering dirt from the mould, the author finds that the kaolin of the body is the effective agent, and that this can (using 5 per cent. kaolin in water) even remove underglaze colour with which a mould has been smeared. He suggests that instead of dipping the air dried or biscuit fired body in glaze, the mould might be first filled with glaze, then immediately emptied and filled with slip, the latter being left in till the desired thickness is attained. Advantages of this process are, that casting and glazing are combined in a single process (air drying and biscuit firing being dispensed with), that the glaze adheres so firmly to the body that neither peeling nor crazing is possible, and that the same intimate combination between glaze and body causes the glaze to show a deeper and darker lustre, and produces a heightened effect (as compared with ordinary glazing) when the body is coloured and the glaze transparent. Disadvantages are that the glaze is always thicker at the bottom than at the rim, that the mould absorbs water from the glaze and therefore quickly becomes damp, and so does not allow so many castings in a working period as when used for casting unglazed objects, and that in many cases the extra moistening of the mould prevents spraying of the mould with glaze by means of dust sprayers.

The same process may be used to cover one body with another of different composition, and if the difference in composition be not too great, no separation arises in firing, even when the melting points of the masses differ 60° or 80°. For protection against weather (as in exposed architectural pieces, etc.)

it is recommended to have an outer layer more difficultly fusible, which may consist of addition of 5 per cent. grog, and may be coloured as desired. Such an outer layer also prevents distortion of the more fusible material inside during the firing. In the case of porcelain, the author found that a more difficultly fusible protective layer between two similar more easily fusible biscuit layers answered well; four vases prepared in this way stood upright among a heap of ruins resulting from too sudden cooling of a muffle, the other contents being ordinary porcelain.

It is suggested that the three-layer porcelains should be well adapted for the production of larger art castings. Such pieces can, if preferred, be air-dried, biscuit fired, glazed, and glost fired in the ordinary way. For the protecting body no general recipes can be given. The casting mixture must be made suitable by increase of kaolin content, and in all cases by addition of other material for raising the melting point in careful trials. As such porcelains (of three layers) are insensitive to sudden temperature changes, they are refractory, and represent a physical solution of an important problem. In the glass industry, two physical methods are used to make glass resistant to sudden temperature changes, the hard glass preparation and the compound glass methods; only the latter is practicable in the case of porcelain. A small pot made of three layers of porcelain was several times in succession heated to redness in the blowpipe flame and then quenched in cold water without cracking.

DETERIORATION OF MOULDS DURING STORAGE.—(*Ker. Rund.*, **26**, 107, 1918). Has reference to Dr. Mellor's paper—see TRANS., **17**, 331, 1918.

WHAT DEMANDS DO CERAMIC FACTORIES PUT ON MOULD PLASTER?—E. Cramer (*Ker. Rund.*, **26**, 169, 175, 1918). See abstract of same paper from *Sprech.*, **51**, 211, 1918.

POTTERY IN VOLHYNIA.—Neumann (*Ker. Rund.*, **26**, 231, 1918). A brief description with an illustration showing a potter at work, and ground plan and sectional elevation of an oven.

DRYER FOR BRICKS.—E. B. Ayres, U.S. Pats. 1,255,685 and 1,255,686, Feb. 5th, 1918. The dryer is divided into chambers or sections with independent air circulation, the last section having a separate supply of heated air which is directly discharged from this section so that the bricks may be thoroughly dried. The chambers of the second dryer are separated by movable curtains, so that bricks can be transferred from one chamber to another.

WARE DRYER.—A. B. Klay, U.S. Pat. 1,256,237, Feb. 12th, 1918. Several compartments one above another are arranged for drying over a firing kiln (or oven) in the basement of the factory. Vertical flues from the kiln pass through the compartments and distribute heat by radiation.

MINERAL WOOL.—W. Fay, U.S. Pat. 1,256,541, Feb. 19th, 1918. Molten slag is discharged from a cupola into a combined blast pipe and mixing chamber, and a blast of steam mixed with a dust-settling fluid is passed into it to form wool-fibres.

ARTICLES OF BLAST FURNACE SLAG.—J. B. Shaw, U.S. Pat. 1,259,304, March 12th, 1918. To molten slag from a blast furnace or cupola is added, while it is settling, an agent to accelerate the liberation of gas. The slag is poured into moulds, and the articles removed from the moulds after a thin superficial crust has formed. The solid crust is then heated to the melting point, the article being surrounded by heated solid material which excludes air and furnace gases, and finally the article is slowly cooled.

DRYER FOR BRICKS.—A. E. H. Beyer, Ger. Pat. 301,583, Jan. 10th, 1913. Chambers arranged in two parallel rows are heated by the waste gases from a continuous kiln, the temperature being controlled by means of dampers.

DRYER FOR BRICKS.—C. H. Klein, U.S. Pat. 1,272,676, July 16th, 1918. The drying chamber contains trucks, each carrying a pile of trays fitting closely against the side walls, the bricks being arranged on the trays. Compressed hot air or gas, entering just above the lowest tray, passes from side to side across each tray in turn (and through connecting ducts in the side walls). Other ducts in the walls allow fresh dry air to be introduced at certain stages. The gases finally escape by an outlet at the top.

V.—FIRING KILNS, OVENS, MUFFLES, ETC.

SMOKE-BURNING OF INDUSTRIAL FURNACES.—O. Boudouard (*Cer.*, **20**, 108, 1917). Relates to a conference held (March 15th, 1917) at the Conservatoire National des Arts et Métiers. A historical discussion of the question, with reference to proposals made and adopted. A table is given with results showing the economy effected by the use of coke in place of coal. Another table exhibits the loss of power through failure to utilise the gases from blast furnaces.

THE STAGES IN IMPROVEMENT OF A TUNNEL KILN.—(*Cer.*, **20**, 121, 140, 197, 1917). Relates to the Dressler tunnel kiln.

ENGLISH PORCELAIN FOR PYROMETER TUBES.—(*Cer.*, **20**, 202, 1917). A short note relating to work done at the National Physical Laboratory.

CERAMIC CONTINUOUS KILNS AND OTHERS.—Cazeneuve (*Cer.*, **20**, 153, 188, 197). A discussion of the conditions necessary for improvement of the produce, with an illustrated description of the author's continuous kiln, the special features of which can be introduced into all existing kilns. These consist of passages arranged under the bottom by means of which the products can be completely and methodically cooled and all the heat collected without injuring the proper management of the fire; with attention there should be considerable economy of fuel, and quicker firing. It has not been possible to test it in actual practice, but the author claims to have had twenty years' experience.

SAGGARS IN ROUND OVENS.—J. Dupagny (*Cer.*, **20**, 201, 1917). A method for quickly estimating the number of bungs of round or oval saggars which can be set in a round oven. In the case of round saggars (as well as ovals) it will be sufficient to know how many bungs can be placed in the first ring in order to find very easily the number for the following rings. It will be sufficient in fact to reduce this first number by 6·4 in order to obtain the number for the second ring, and to continue this until a number not greater than 6·4 is obtained. This factor 6·4 is constant, and applicable to every size of round oven or kiln and to every size of round saggar. Thus if the first ring takes 44 saggars,

the second ring will take	44	$-6{\cdot}4=37{\cdot}6$	or practically	37
,, third ,,	,,	$37{\cdot}6-6{\cdot}4=31{\cdot}2$	,,	31
,, fourth ,,	,,	$31{\cdot}2-6{\cdot}4=24{\cdot}8$	,,	24
,, fifth ,,	,,	$24{\cdot}8-6{\cdot}4=18{\cdot}4$	,,	18
,, sixth ,,	,,	$18{\cdot}4-6{\cdot}4=12$	,,	12
,, seventh ,,	,,	$12\ -6{\cdot}4=\ 5{\cdot}6$	,,	5

or a total of 171 bungs. These would evidently be saggars of rather small size, but the same method holds for larger ones, of which there would not be so many in first ring. When the last number is at least equal to 6·4 an extra bung can be reckoned for the centre.

For oval saggars the method of calculation is similar, with 8 or some other number instead of 6·4. The exact number depends on the ratio between the axes of the saggars.

The number of saggars in the first ring can be calculated from the diameter of the circle passing round through the centres of the saggars. From the diameter the circumference is easily found, and this is simply divided by the diameter of a saggar, or (if not round) by the width of the saggar along the circumference. Due allowance is to be made for spaces left between the saggars or between the saggars and the wall of the oven. It may be added that the number 6·4 has been tried by use. Theoretically it should be 6·28, but the 6·4 allows for irregularities.

PRODUCTION AND MEASUREMENT OF HIGH TEMPERATURE.—E. F. Northrup (*Pot. Gaz.*, **42**, 1,151, 1917). Report of paper read before the Faraday Society. Refers mainly to a special type of electric furnace, and a tin-pyrometer.

AUTOMATIC CONTROL AND MEASUREMENT OF HIGH TEMPERATURES.—R. P. Brown (*Pot. Gaz.*, **42**, 1,151, 1917). A brief description of the Brown Heat Meter.

MEASUREMENT OF HIGH TEMPERATURES BY MEANS OF POTTERY MATERIALS.—H. Watkin (*Pot. Gaz.*, **42**, 1,151, 1917). A review of the application of properties like contraction and fusibility for determination of temperatures, including Watkins' heat recorders, Seger cones, the Wedgwood pyrometer, Buller's rings, etc.

PROPER DRAUGHT CONDITIONS IN BURNING KILNS.—A. E. Williams (*Brick*, **51**, 220, 1917). Evidence shows that the quantity of fuel used per unit of time after a kiln has been lighted twelve hours does not change much, being about the same in getting the kiln hot as in keeping it hot afterwards. Fuel economy is thus largely a matter of saving time. In most cases time in burning can only be saved during the heating-up, and very little within the period of settling or vitrifying the ware. To hasten the heating-up portion of the burn, a very good initial draught and a wide range of draught control are necessary, conditions rarely possible with ordinary chimneys less than fifty feet high.

To obtain proper distribution of heat in a down-draught kiln, the floor openings must be greatly constricted, and this usually tends to give very poor initial draught conditions. Thus a kiln at finishing heat with a proper floor gives a draught of 0·22 inch on a differential draught gauge when the damper is wide open. The draught at the beginning of the burn would be only 0·05 to 0·01 inch, so that the chimney has to be warmed up before the burning can be pushed and the moisture removed from the kiln rapidly enough. The desirable condition would be a draught of 0·30 inch at the beginning of the burn and a damper adjustable to give the proper draught for finishing, which would be 0·16 to 0·20 inch for oxidizing conditions. With proper heat distribution this can only be arranged by greatly increasing the draught so that a high draught can be concentrated on particular kilns when required. There are three ways of doing this: (1) A large stack connected with ten or twelve kilns; (2) a positive fan draught connected to twelve or more kilns; (3) a small fan on a movable platform, for connecting to the chimney flue of any kiln.

In the first case a chimney 175 to 200 feet high placed in the centre of a large collecting flue suffices for ten to fourteen kilns, small connecting tunnels joining each kiln to the collecting flue. (A 200 feet stack in Illinois provides draught for sixteen brick kilns. The stack is 16 ft. 2 in. at the bottom and 9 ft. at the top, with a 30 ft. square reinforced concrete foundation).

A large fan may replace the large chimney, the flue system being similar to that used with the dryer fan. Fan draught is largely used on continuous kilns, and seems to be very much more desirable than chimney draught; one fan would suffice for 25 to 30 kilns.

A small fan applied to a chimney during the early stages of a burn has proved to be a great time saver, and is satisfactory on an old plant where the construction of a large draught unit is not feasible.

With proper draught arrangements, one-and-a-half to two days or even more may be saved in the time of burning of brick kilns.

Table Showing Relative Draught for Different Heights of Chimney.
Internal Air 552° F. External Air 62° F.

Height of chimney (ft) - -		10	20	30	40	50	60	70
Draught power (inch of water)		0 073	0.146	0·219	0 292	0·365	0·438	0 511
Theoretical velocity in ft. per second	Cold air enters	17·8	25 3	31·0	35·7	40·0	43·8	47 3
	Hot air at exit	35·6	50·6	62 0	71·4	80 0	87·6	94·6
Pounds of coal which can be burned per sq. ft. of grate -		4·00	7·50	9 50	11·60	13·10	14·50	15·00

Table Showing Relative Draught for Different Heights of Chimney.
Internal Air 552° F. External Air 62° F.

Height of chimney (ft.) - -		80	90	100	120	150	175	200
Draught power (inch of water)		0·584	0·657	0·730	0·816	1·095	1·277	1·460
Theoretical velocity in ft. per second	Cold air enters	50·6	53·7	56·5	62 0	69·3	74·3	80 0
	Hot air at exit	101·2	107·4	113·0	124·0	138 6	149·6	160·0
Pounds of coal which can be burned per sq. ft. of grate -		16·90	18·00	19·00	21·00	23·50	25·45	27·28

The maximum rate of watersmoking and the time required for oxidation should be separately determined for each product. Clay products dried in hot air at 250° to 300° F. require no special treatment during watersmoking, but ware dried in the open air dryer, etc., at a temperature rarely above 100° F. will crack very easily with too rapid water smoking. In one works the brick kilns are showing red in upper courses at the end of 24 hours. In another works six-inch tiles are burned within 48 hours, the watersmoking temperature for the first 24 hours being not over 300° F. The temperature at which oxidation proceeds best in shales is between 1,300° and 1,450° F., and the temperature may always be raised quickly to this point even when the black centre can only be burned out slowly.

BURNING SALT-GLAZED VITRIFIED WARE.—S. C. Karzen (*Brick*, **51**, 846, 1917). Reprinted from *Trans. Amer. Cer. Soc.*, **18**, 431, 1916.

OXIDATION AND ITS CONTROL.—S. C. Karzen (*Brick*, **51**, 1,028, 1917). A discussion of the conditions during oxidation, and the means of control in firing clayware. It is necessary chiefly for shales, fireclays seldom giving trouble.

MORTAR FOR KILN MASONRY.—(*Brick*, **51**, 232, 1917). For the outside wall of a rectangular brick kiln in Illinois a very satisfactory mortar was made by mixing one wheelbarrow each of grog sand (from bricks) and shale, and two sacks of Portland cement. For use about the fire-boxes three shovels full of the same sand were mixed with four shovels full of Missouri fireclay.

INSULATING KILN CROWNS.—(*Brick*, **51**, 955, 1917). Attention is called to the fact that much of the loss of heat due to radiation might be prevented by insulating the kilns. This can be done by building thick walls and covering the crowns with cement, ashes, platting, or some kind of roof. Kieselguhr would be the best material.

DOWN-DRAUGHT BISCUIT KILN.—(*Brick*, **51**, 703, 1917). A short paragraph relating to a kiln (or oven) patented by George Latinski, which is said to use 35 to 40 per cent. less fuel, to accommodate 420 more saggars than the ordinary oven, to reduce breakage, and to take 12 hours less for the firing.

MANAGEMENT OF GAS PRODUCER FOR GAS-FIRED KILN.—(*Brick Pot. Tr. J.*, **25** 149, 1917). Remarks mainly referring to practice.

SAGGARS.—(*Brick Pot. Tr. J.*, **25**, 188, 1917). A general discussion, including a reference to mending operations.

USING THE PERISCOPE IN BURNING.—(*Brick Pot. Tr. J.*, **25**, 198, 1917). An illustrated note from *Tonind Ztg.* See also TRANS., **18**, Abs. , 1919.

NEW UP-DRAUGHT KILN.—(*Brick Pot. Tr. J.*, **25**, 219, 1917). An illustrated account of the kiln forming the subject of Patent No. 107,678, by T. West and W. J. G. Lewis, dated July 28th, 1916. See reference in TRANS., **17**, Abs. 30, 1918.

FIRING UP-DRAUGHT AND DOWN-DRAUGHT KILNS.—(*Brick Pot. Tr. J.*, **25**, 220, 1917). An article by J. D. Pratt in *Brick*.

CLINKERS: THEIR CAUSE AND PREVENTION.—(*Brick Pot. Tr. J.*, **25**, 223, 1917). Hints for treatment of fuel during firing.

KILN FURNACE DATA.—(*Brick Pot. Tr. J.*, **25**, 234, 1917). A brief survey of available data. Taken from *Brick*.

BRICKS FOR KILN-MOUTHS.—(*Brick Pot. Tr. J.*, **25**, 245, 1917). As far as clinker is concerned the smoother and finer-grained the bricks, the more durable they would be likely to prove. But fine-grained bricks are liable to crack with sudden changes of temperature. It is advantageous to use fairly fine-grained fireclay bricks in the sides of the kiln-mouths, and for the bags, but coarser bricks are desirable for the arches.

Trouble in clinkering would be saved by properly cleaning the side walls of the mouth of the fireplace each time the kiln is to be used, but the brickwork should not be chipped away too much when removing the slag or clinker.

The possibility is suggested of an iron plate—preferably air-cooled—at each side of the fuel proving a useful protection of the brickwork.

THE FIRING OF POTTERY OVENS.—S. T. Wilson (*Pot. Gaz.*, **42**, 479, 1917). See also TRANS., **16**, 304, 1917.

REFRACTORIES AND MODERN KILNS.—J. G. Maxwell (*Pot. Gaz.*, **42**, 1,069, 1917). See also TRANS., **17**, 57, 1918.

THEORY AND PRACTICE OF FIRING.—J. Burton (*Pot. Gaz.*, **42**, 1,071, 1917). A review of the course of firing operations and of necessary precautions, including the phases presented during cooling.

MAGNETITE LININGS (MONOLITHIC) FOR BASIC COPPER CONVERTERS.—A. E. Wheeler and M. W. Krejci (*Trans. Amer. Institute of Mining Eng.*, , ,). Relates mainly to monolithic magnetite linings. In the converter process for the production of copper, matte is blown up to metallic copper in a modified type of Bessemer converter. Matte may be roughly defined as a mixture of sulphides of copper, iron, nickel, silver, etc. The conversion of matte consists mainly in removal of sulphur as SO_2, and slagging of the iron. Formerly acid (siliceous) linings were used for the converters, but latterly nearly all the converters have been basic lined, such linings having a much longer life. The silica required is introduced into the converter (as siliceous ores or otherwise) through the mouth or the tuyeres. The iron shell of the converter has usually a magnesite brick lining 9 to 30 inches thick, the thickest lining being at the tuyeres where the temperature is high and intense chemical action takes place. The varying temperatures cause the bricks to crack and spall, and exceptionally high temperature produces softening, in all cases accompanied by wear of the lining. To guard against this wear, new converters were charged with white metal, which was then blown to copper, coating the lining with white metal and copper; this treatment was repeated several times before blowing matte. But this coating was easily melted off, leaving the bricks exposed, and many basic linings lasted only a few days, whereas basic linings properly protected (as below) have lasted over two years.

It was soon found to be quite as good to immediately blow matte for a few minutes (until temperature is getting dangerously high), allowing the charge to stand 15 or 20 minutes, again blowing, and so on until the bricks were coated with a layer of matte.

Eventually the magnetite formed from this charge was used with great success. Magnetite is formed in artificial magmas, especially when the silica is low. The melting point of magnetite is given as 1,527° to 1,538° C., and this is greater than the melting point of the charge.

For applying this lining to a new converter, the latter is gradually heated to bright redness, and charged with liquid matte (preferably low grade, say 35 per cent.), which is blown for 10 to 15 minutes, when cooling material (cold matte) is added to lower the temperature. Blowing and addition of cold matte are continued alternately until the charge is blown to white metal. No ore or other siliceous material having been added, the converter has become lined internally with the magnetite formed. Fresh liquid matte is added, with not quite enough silica, and blowing continued in the regular way until the lining is thoroughly coated and no brick exposed. Afterwards silica sufficient to flux the iron is used. Once a converter is lined it should never be re-lined. Should the coating become too thick, the temperature and the silica of the charge can be increased, to remove part of the coating, and *vice versa* if by excessive wear the bricks become exposed.

Data are given bearing on the working of converters. Time-temperature curves are also given. The authors think it possible to use a cheaper original lining than magnesite, but have not yet demonstrated this experimentally.

POWDERED COAL IN THE CERAMIC INDUSTRIES.—W. G. Wilcox (*Brick*, **54**, 127, 1919). The author cites instances showing that increased efficiency may be obtained in certain reverberatory furnaces by use of powdered coal so as to get complete combustion with a short, hot flame. This increased efficiency probably results from the operator being able to maintain the flame length and type of combustion best suited to the furnace design. In changing from hand-fired practice to powdered coal combustion, it is found that only 30 to 40 per cent. as much coal is required.

By grinding an inch cube of coal so fine that 85 per cent. will pass a 200 mesh, the exposed surface has been increased from 6 sq. inches to about 1,800 sq. inches, the velocity of combustion being thus increased about 300 fold. The temperature of all the material is thus raised much more quickly, and this temperature rise will itself double the velocity of combustion for each rise of 10° C., thus adding to the effect.

Finely divided fuel can be intimately mixed with air, and with a proper velocity of the air current the fuel can be carried into the furnace with it and there burned completely, efficiently and rapidly, the amount of fuel and of air being under control. The length of flame depends on nature of combustible, excess of air, and rate of firing, and also on the rate of mixing of the combustible (gases or dust) with the oxygen of the air. Powdered coal has the characteristic of a rich fuel of somewhat higher kindling temperature than producer gas, natural gas or fuel oil.

When powdered coal is fired at high pressure and high velocity, combustion frequently does not begin until a point 4 to 6 feet from the mouth of the burner. High pressure, high velocity firing not only slows down combustion, thus increasing the size of combustion chamber necessary, but has a destructive action on the furnace, aggravated by the fluxing action of the melted ash. Slowing down the velocity not only hastens combustion, but makes it possible to eliminate much of the slagged ash (by a slight change in direction of the flame if necessary). The combustion chamber should be maintained above a certain minimum temperature, and combustion should be practically complete before the products of combustion pass over the heat absorbing surfaces. With an intimate controlled mixture a long flame can only be produced by supplying insufficient air

Coals running as high as 30 to 40 per cent. ash can be successfully burned, but with low flame temperature. Even lignite fuels are burned successfully in

powdered form, while coals not usable (because of nature of ash) in the ordinary way make good powdered fuel.

It is suggested that powdered fuel might perhaps be adapted for the ceramic industries.

SAVING OF TIME IN BURNING BRICKS.—(*Brick*, **54**, 869, 1919). Describes how a manufacturer of common bricks was able to reduce the time for burning bricks in coal-fired, 28 ft., down-draught round kilns from over seven days to three and a half days, at the same time saving 310 lb. coal per thousand bricks.

The floor system of the kiln consists of one central cross-collecting flue, 6 to 7 feet deep and 24 inches wide, running at right angles to the main stack flue, which is 3 feet wide and 3 feet deep to the spring of the arch. In the cross-collecting flue are openings 4 inches by 24 inches, which are 8 inches apart. Smaller distributing flues are left in the setting of the bottom courses of green bricks. The kiln has eight small fireboxes about 18 inches wide, 20 inches high, and 43 inches deep to bag wall. The charging hole is about 12 by 12 inches, and is covered by a fireclay slab or (better) eight grooved and tongued firebricks. About 18 inches behind the front outside wall of the firebox an air chamber 25 by 13 by 18 inches is built in the floor of the firebox, the construction being of common bricks and cement mortar except at the top, where it is firebricks and fireclay. Fitted on top of this chamber is a perforated (with $\frac{1}{8}$ inch holes one inch apart) cast-iron grate, 15 by 25 inches, and $\frac{3}{8}$ inch thick. Forced draught is used, and the cost of installing and operating the system is very low, and it is soon effected. The article is amply illustrated.

HEAT BALANCE OF A CONTINUOUS CHAMBER KILN.—C. Treischel and H. S. Robertson (*J. Amer. Cer. Soc.*, **1**, 322, 1918). Report of investigation of a brick kiln, of the moving fire type, with fourteen chambers in one continuous row, and fired by producer gas.

The results of the author's calculations show 3·15 per cent. of the heat lost by carbon in the ashes, 27·45 lost by gasification in the producer, 22·3 used in burning the ware, 33·7 lost by waste gas, 0 lost in water-smoking gases (which leave at a high humidity and at atmospheric temperature), and 13·4 per cent. lost by radiation and conduction.

THE ZWERMANN TUNNEL KILN.—C. H. Zwermann (*J. Amer. Cer. Soc.*, **1**, 262, 1918). A description (with drawings) of an oil-fired kiln, 352 feet long, with tunnel 6 ft. 4 in. wide and 6 ft. 6 in. high, accommodating altogether 46 trucks each 7 ft. 7½ in. long. The loaded trucks are introduced singly at two-hour intervals, the whole time required to pass a truck through the kiln being 92 hours. The kiln gases are drawn off by means of an exhaust fan near the entrance end, mechanical draught being preferred because of the closer control which it enables the fireman to exercise. A second exhaust, near the middle of the kiln, draws cold air through the hollow arch and side walls of the cooling zone. This pre-heated air is used for drying and pre-heating the ware. A pressure blower at the outlet end of the kiln delivers the air for combustion, this air passing through recuperates in the side walls of the cooling zone.

Ten oil burners are used, arranged in opposite pairs at the ends of the firing zone, with the remaining six alternating on the two sides of the kiln. Eight of the trucks are opposite the burners, and each burner can be regulated so that no considerable variation of temperature takes place for days and weeks. When working under proper control, the greatest temperature difference found between the top and bottom of a truck load was about one-half cone, the ware being burned to cone 9.

A second kiln, 285 feet long, is also in use at the same works.

DRAUGHT MOVEMENTS IN FLUES.—E. H. Fritz (*J. Amer. Cer. Soc.*, **1**, 294, 1918). Ordinary draught gauges are apt to be misleading, as shown by Harrop, because they only measure the static pressure (or pressure required

to overcome the resistance offered to the flow). To this should be added the velocity pressure (or pressure causing the rate of movement or velocity of flow of gases). The sum of these two gives the total pressure or draught intensity of a stack. Velocity pressure does not as a rule vary directly with the static pressure. In the investigation the static pressure between two points in a flue was taken as a basis. The apparatus consisted of static pressure tubes inserted at the two points in a flue, each tube being connected with one end of a U-tube, as used on the draught gauge. A differential reading giving the friction between the two points was then taken. With induced draught, the static pressure gives a higher reading than the total pressure, and as both are negative, by subtracting the former from the latter a positive value is obtained for velocity pressure. A possible method of using the draught gauge to measure velocities and weights in a flue is thus indicated.

COAL GAS AS A FURNACE FUEL.—H. Hartley (*J. Soc. Chem. Ind.*, **37**, 65R, 1918). A discussion of some applications of coal gas to metal melting furnaces, etc.

MELTING POINT OF COAL ASH.—J. T. Dunn (*J. Soc. Chem. Ind.*, **37**, 15T, 1918). Gives details as to composition and approximate melting point of the ash of a number of different coals.

TEST OF A PRODUCER-GAS-FIRED PERIODIC KILN.—C. B. Harrop (*J. Amer. Cer. Soc.*, **1**, 35, 1918). A detailed account of the testing of a down-draught round brick kiln. The total radiation and convection loss were not ascertained accurately, but the author believes it might be as low as 10 per cent. and not over 15 per cent. The producer and flue loss was calculated to be over 13 per cent., which, as far as heat generation goes, is not more efficient than the combustion of coal in the kiln furnaces, but the ability to control the application of the gas to the kilns is an advantage, the excess of air being much lower than in most direct coal-fired kilns. Either oxidizing or reducing conditions may be secured as desired, and quickly reversed whenever necessary. The advantages of the system include centralization of coal and ash, clean kiln yard, reduced kiln yard space, combustion control, generation of a large amount of heat in a limited furnace space, quick burns and labour-saving when more than one man is ordinarily required. The disadvantages are producer and flue losses, and lower flame temperature.

HEAT BALANCE ON A PRODUCER-GAS-FIRED CHAMBER KILN.—R. K. Hursh (*J. Amer. Cer. Soc.*, **1**, 567, 1918). A record of data obtained with a 16-chambered brick kiln.

The heat balance is shown for the gas producer and the kiln separately and together. The heat balance of kiln and producer combined shows 43·59 per cent. of the total heat (from coal, air, steam, and carbon in clay) as used to raise the temperature of the clay and drive off water, 32·35 loss due to sensible heating of flue-gas, 8·72 loss due to conduction, radiation, etc., from kiln, 14·72 loss due to conduction, radiation, etc., from producers, and 0·62 per cent. loss due to unburned carbon in ashes.

CAR TUNNEL KILNS FOR BRICKS, etc.—E. Lovejoy (*J. Amer. Cer. Soc.*, **1**, 628, 1918). A general discussion of the difficulties to be surmounted in adapting such kilns for products of crude clays.

TUNNEL KILN FOR HIGH GRADE CLAYWARE.—S. (*Ker. Rund.*, **26**, 85, 1918). Relates more particularly to the kiln described in L. E. Barringer's paper in *Trans. Amer. Cer. Soc.*, **18**, 106, 1916—see TRANS., **16**, Abs., 106, **1917**. Several other references to tunnel ovens are given.

GAS GENERATORS AND GAS FIRING.—O. Happach (*Ker. Rund.*, **26**, 89, 101, 113, 121, 144, 158, 1918). An illustrated account of different forms and different processes.

SUPERINTENDENCE OF THE FIRING IN THE GLASS, ENAMEL, AND CLAYWARE INDUSTRIES.—L. Springer (*Ker. Rund.*, **26**, 187, 191, 206, 211, 215, 219, 1918). A general survey of the subject, with special regard to present conditions. The four general headings relate to investigation of fuel (mainly coal), testing of heating gases and smoke gases, measurement of draught, and measurement of temperature. For low temperatures, the ordinary mercury thermometer can be used up to about 350° C., and by the aid of a special glass which first softens at 667° C. a nitrogen thermometer can be used up to 550° C. The melting points of certain metals and alloys give a number of fixed points: tin 232°, bismuth 270°, lead 327°, zinc 420°, aluminium 660°, silver 960°, gold 1,060°, nickel 1,480°, platinum 1,710° C., with a number of intermediate temperatures represented by the melting points of various alloys of silver and gold and of gold and platinum. Seger cones may also serve to measure temperatures of 600°—2,000° C. at intervals averaging about 20° C. Seger cones are generally used in the clayware industry, and the author considers they should be also used much more in the glass and enamel industries. Electric pyrometers are briefly alluded to (both resistance and thermoelectric pyrometers), and optical pyrometers. The importance of measuring temperatures in the glass industry is emphasized.

TUNNEL KILN.—J. B. Owens, U.S. Pat. 1,251,273, Dec. 25th, 1917. The kiln has a space formed by a wall built along each side within the kiln beyond the maximum temperature zone. Air passes into this space through an opening in the top of the kiln, and after taking up heat from the cooling goods it passes on to the furnace for combustion of the fuel.

SECTIONAL KILN.—R. H. McElroy, U.S. Pat. 1,264,316, April 30th, 1918. A rectangular kiln with perforated bottom has sections arranged longitudinally, each section having at the sides bag-walls, which form passages for the hot air and combustion products, together with longitudinal connecting flues between the sections, and lateral flues for hot air; the two latter may be transposed if preferred.

COMPARTMENT KILN.—R. H. McElroy, U.S. Pat. 1,264,317, April 30th, 1918. The compartments of a kiln are connected by flues so arranged that several compartments may be heated together. The compartments are also connected by air flues, which are themselves connected by lateral flues, and these may by means of a hood be connected with either the main flue or the waste heat flue through uptake flues.

SYSTEM OF ROUND KILNS.—J. T. H. Warwood, U.S. Pat. 1,264,722, April 30th, 1918. A number of round kilns having fire boxes, perforated hearths, and vertical flues, are connected through their perforated hearths with an upper, central, longitudinal flue, and by the vertical flues with a lower, central, longitudinal flue. The upper and lower flues connect with one another through ports regulated by dampers, and an upper lateral flue and transverse flues meet the upper central flue between the ports and the dampers. A lower lateral flue connects with the lower central flue through a transverse passage and to an exhaust. The connections to the lower and upper central flues may be interchanged.

EARTHENWARE OVEN.—J. Litinsky, U.S. Pat. 1,265,097, May 7th, 1918. Relates to a three-storey, round pottery oven. The middle storey is the primary chamber, and has a thin floor and ceiling through which short gas-flues pass to connect with the lower chamber. Fireboxes of the usual kind are arranged around the middle chamber. In the lowest chamber additional fireboxes transmit hot gases through holes in the floor of this chamber and also along vertical flues and through holes in the floor of the uppermost chamber. This top chamber is worked with up-draught only, but the other two chambers may be worked with either up-draught or down-draught.

TUNNEL KILN FOR DRYING AND FIRING.—J. Janka-Vales, Ger. Pat. 304,016, Aug. 9th, 1916. The kiln has two storeys. Ware is dried on the wagon in passing through the upper storey, and then fired and cooled in returning through the lower storey. A fan between the drying and cooling chambers circulates air, which passes along under the firing chamber through a flue (the roof of which is formed by the floors of wagons), and thence back to the top storey.

TUNNEL MUFFLE KILN FOR CERAMIC PRODUCTS.—A. Krautzberger, Ger. Pat. 306,055, May 17th, 1917. The tunnel has one or several muffles at the side, heated externally. Cars with goods pass along as usual until they reach a muffle into which the goods are pushed and left to attain the maximum temperature desired. They are then drawn back on to the cars, and gradually passed through the rest of the tunnel. The goods only stay in the muffle about 10 minutes, so that the kiln practically works continuously.

PORCELAIN KILN.—W. Mellor, U.S. Pat. 1,275,285, Aug. 13th, 1918. Relates to an up-draught muffle kiln with several fireboxes on one side, below the level of the bottom, connected to flues below the bottom and to vertical flues. There are two chimneys at the top, one for each side of the kiln.

TWIN TUNNEL KILN.—C. H. Zwermann, U.S. Pat. 1,275,352, Aug. 13th, 1918. See abstract of paper by Zwermann in *J. Amer. Cer. Soc.*, **1**, 262, 1918.

COMPARTMENT KILN.—R. H. McElroy, U.S. Pat. 1,275,712, Aug. 13th, 1918. Relates to a gas-fired continuous kiln of the transverse arch type, each chamber being provided with a transverse bag wall along one side, a feather-wall forming a connecting flue, and a floor which is perforated except portions adjoining the bag wall. The connecting flues and floor-perforations communicate with the main flue.

BRICK-KILN.—E. H. A. Bollbuck, U.S. Pat. 1,277,539, Sept. 3rd, 1918. Relates to a kiln having stationary partitions fitted with doors so as to form compartments communicating in series, also in parallel when the doors are opened. Independent furnaces or burners above the kiln are connected with the different departments, and dampered flues in the lower portion of each compartment are connected with the main flues in the kiln walls.

KILN FOR CERAMIC WARE.—O. von Horstig, Ger. Pat. 306,726, July 3rd, 1914. Relates to a zigzag ceramic kiln with the end chambers connected by a channel which passes over or under the other chambers, and is provided with firing doors.

SMOKELESS FIRING OF PORCELAIN, etc.—J. Popp, Ger. Pat. 307,902, Sept. 29th, 1916. The oven has deep vertical fireboxes with water-cooled, sloping grates covered by narrow movable slides. Production of smoke and clinker is avoided even with low-grade fuel, and much fuel and labour are saved.

DRAUGHT IN TUNNEL KILNS.—J. B. Owens, U.S. Pat. 1,278,991, Sept. 17th, 1918. The kiln is divided into two compartments by a horizontal platform which engages in longitudinal lateral grooves. The upper compartment, in which the ware is placed, is heated strongly, and air for cooling is admitted under regulation to the lower compartment to protect the contrivance (placed below the platform) for conveying the ware. Air leaks slowly, through the spaces between the walls and the platform, into the upper compartment.

THE WORKING OF VERTICAL RETORTS.—E. Garsed (*Gas World*, **68**, 199, 1918). The presidential address to the Yorkshire Junior Gas Association on the continuous working of vertical retorts.

VERTICAL RETORTS AT BRADFORD.—E. Gillett (*Gas World*, **68**, 330, 1918). A paper entitled "Repairs and Maintenance Costs for a Two Million Cubic Feet per Day Glover-West Retort Installation."

STEAMING HORIZONTAL RETORTS.—R. J. Rew (*Gas World*, **68**, 321, 1918). A summary of results obtained by steaming horizontal retorts at a small gas-works, with boiling tests, analyses, etc.

HOME-MADE BLUE WATER GAS PLANT.—A. R. Wyatt (*Gas World*, **68**, 322, 1918). An illustrated description of a plant for a small works, laid down on lines suggetsed by W. W. Townsend in *Gas World*, Nov. 17th, 1917. The whole cost did not exceed £50.

VERTICAL RETORTS WITH AND WITHOUT STEAMING.—(*Gas World*, **69**, 154, 180, 214, 1918). Letters from H. J. Toogood, J. West, and H. J. Toogood, discussing results obtained by these methods.

WATER GAS IN CONTINUOUS VERTICAL RETORTS.—H. M. Balsam (*Gas J.*, **141**, 247, 1918). An account of the production at Pernambuco (Brazil) of gas consisting of half coal gas and half water gas.

VERTICAL RETORTS.—E. Garsed (*Gas J.*, **141**, 396, 1918). Presidential address on continuous working of vertical retorts. On p. 453 is a letter by J. West criticising the paper, and also a letter from T. Settle.

HIGH AND LOW TEMPERATURE COAL CARBONIZATION.—F. M. Perkin (*Gas J.*, **141**, 504, 1918). A letter referring to articles in the "Financier."

VERTICAL RETORTS.—(*Gas J.*, **142**, 269,376, 1918). The first item is an editorial article, and the second relates to vertical retorts at Tottenham gas-works.

HORIZONTAL RETORTS.—R. J. Rew, etc. (*Gas J.*, **142**, 280, 1918). A summary of results obtained by steaming, including also boiling tests and analyses. On p. 326 is a short editorial note relating to *West and Wild's* continuously worked horizontal retorts.

CONTINUOUS VERTICAL RETORTS.—(*Gas J.*, **143**, 65, 1918). Results obtained with the Dempster-Toogood system by T. Duxbury at Oldham.

CONTINUOUS VERTICAL RETORTS.—(*Gas J.*, **143**, 532, 1918, and **144**, 27, 130, 1918). Letters from H. J. Toogood, J. West, and H. J. Toogood relating to results. Reference is also made to a table in lecture by Prof. Cobb on p. 484 of vol. 143.

SETTLE'S DOWNWARD-STEAMING PROCESS.—(*Gas J.*, **144**, 348, 356, 1918). Editorial and communicated articles on tests of the process for intermittent vertical retorts.

STEAMING IN HORIZONTAL RETORTS.—(*Gas J.*, **144**, 425, 1918). A short account of some results obtained at Maple.

INTERMITTENT VERTICAL RETORTS.—(*Gas J.*, **144**, 524, 1918). A short account of an installation at Rochester (N. Y.), with some results obtained.

CONTINUOUS VERTICAL RETORTS.—F. M. Perkin (*Gas J.*, **144**, 651, 658, 1918). Report of lecture on "Oil from Mineral Sources," with editorial comments (p. 651).

CHAMBER OVENS IN MEDIUM SIZED WORKS.—(*Gas J.*, **144**, 660, 1918). Relates to ovens in gas-works at Ann Arbor (Mich.).

KOPPER'S CHAMBER OVENS FOR COAL GAS MANUFACTURE.—(*J. für Gasbeleuchtung*, **68**, 433, 455, 1918). Short account taken from abstract in *J. Soc. Chem. Ind.*

VI.—GLAZES AND GLAZING. ENAMELS.

DUTCH TILE GLAZES, etc.—B. (*Tonwar. Ofen. Ztg.*, **41**, 142, 162, 1917). Dutch tile glazes often run, not so much on account of the press (which may not have given sufficient pressure), but because of unsuitable adhesive, dextrin or its substitute. Too great an addition of this often causes running of the glaze as well on the edges as at the middle point. The glaze also runs easily when blood and dextrin in equal parts and in too great quantity happen to be in the mixture, and the whole glaze mass is insufficiently stirred with the loam and manganese. It is best to put the dextrin or its substitute (or dextrin mixed with substitutes) with skimmed milk in a small vessel, and stir to a stiff paste. The glaze is also prepared in similar condition, and then the milk-dextrin preparation added to it. The stirring is important too, for as soon as the dextrin powder or its substitute quite loses the dry quality of the powder and has liquefied, the glaze will easily become too fluid. The vessel is allowed to stand 15 minutes after addition of the milk-dextrin preparation to the glaze. The consistency changes in this time, and the mixture is then stirred until no deposit is present. If glue is used instead of dextrin, first class joiner's glue should be used, but only about 10 per cent. For a good smooth glaze it is advantageous, especially when the loam is soluble with difficulty in the glaze, to employ potash, at the rate of $\frac{1}{4}$ to $\frac{1}{3}$ litre dissolved potash with 3 to 4 litres glaze material. The potash is before blending dissolved to a pasty condition with milk and borax water and then added to the not too finely ground glaze and thoroughly stirred. In order to adjust the glaze well to the body, it must be ascertained by small trials which state of grinding (with a slight addition of adhesive substance) best suits the body. Running of the glaze can also arise through changed raw material in the clay pit. Every glaze, whether a smooth glaze or a light coloured glaze, is carried well on the tile and adheres well, if after the standing mentioned above the thin ingredients of the glaze are decanted and it is then stirred again. Some remarks are added concerning green and dark red iridescent glazes, but no compositions are given. Reference is also made to glazes for retorts, salt glaze, etc.

NEW METHOD OF GLAZING.—L. Wunder (*Brick Pot. Tr. J.*, **25**, 148, 1917). See TRANS, **16**, Abs. 99, 1917.

NEW GLAZE.—(*Brick Pot. Tr. J.*, **25**, 231, 1917). Relates to a glaze free from alkali consisting of 84 parts magnesium carbonate, 162 zinc oxide, 1,379 barium carbonate, 720 quartz, and 130 kaolin for fritting, and 2,105 parts frit with 130 kaolin for glazing.

DRYNESS OF GLAZE INSIDE EARTHENWARE JUG.—F. Turner (*Pot. Gaz.*, **42**, 41, 1917). See also TRANS., **17**, 203, 1917.

SALT GLAZING.—(*Brick*, **51**, 780, 1917). A short note. The brightness or smoothness of finish of a salt glaze is little affected whether free silica is in the clay in a fine state or not (40 mesh or finer). Thus a fine sand added to a sewer-pipe body to facilitate safer and more rapid drying should not materially affect the condition of the salt glaze.

The addition of calcium or magnesium sulphate to a sewer-pipe body tends to give the salt glaze a rich brown colour even when a small quantity is added. A large quantity of fine silica added to a sewer-pipe mixture makes the salt glaze lighter coloured.

ENAMELLING PRACTICE.—J. Schäfer (*Stahl u. Eisen*, **38**, 257, 1918). As a result of war time difficulties which had to be solved, enamel mixtures have been made up without borax, the composition resembling that of glass but with higher content of alkaline and alkaline earthy oxides, so that the melting point was much lower than that of ordinary glass. In place of nitre were proposed potassium permanganate, barium peroxide, and sodium peroxide; even atmospheric oxygen has been drawn in for purification purposes. All

substitutes have inherent disadvantages. Apart from lustre, white enamels can be obtained very well by the aid of the usual fusible materials without oxidizing additions. With the present scarcity of materials the making of grey clouded enamels is recommended, which render possible also a saving of opacifying materials. As substitute for tin oxide have been used with good results zirconium compounds, zinc sulphide, clay, as well as mixtures of magnesia or zinc oxide with alumina. Another point to be emphasized is to aim at a complete saving of ground enamel.

EFFECT OF THE DEGREE OF SMELTING ON THE PROPERTIES OF A FRIT.—E. B. Poste and B. A. Rice (*J. Amer. Cer. Soc.*, **1**, 221, 1918). A commercial enamel composition was melted under conditions involving a large variation in the time of smelting, and the enamel produced was subjected to certain tests. The following were the general conclusions: In general the chemical composition of a frit at the point of normal pouring may differ quite materially from the composition which would be expected based on theoretical computation. The chief differences found were that the silica content was higher, the alumina, lime and potash slightly higher, and the soda and boric oxide much lower than the theoretical composition would indicate. At an earlier stage it approximates to the computed composition except as to the boric oxide. Further heating results in rapid increase of the silica percentage, and decrease in the percentage of soda and the boric oxide.

These chemical changes raise the maturing temperature of the enamel but reduce the deformation range. The computed coefficient of linear expansion falls rapidly.

COBALT-URANIUM GREEN GLAZE FOR TERRA-COTTA.—H. Wilson (*J. Amer. Cer. Soc.*, **1**, 233, 1918). A record of experimental trials. Promising results were obtained by the addition of 6 per cent. uranium oxide and 3 per cent. cobalt sulphate to a matt glaze of the composition $0{\cdot}261K_2{\cdot}0{\cdot}306CaO_2$ $0{\cdot}294ZnO{\cdot}0{\cdot}083BaO{\cdot}0{\cdot}057MgO{\cdot}0{\cdot}384Al_2O_3{\cdot}2{\cdot}08SiO_2$. The matt glaze matures at cones 3 to 7 in a commercial kiln, and the coloured glazes were fired in a commercial terra-cotta muffle kiln to cone 6—7.

GROUND COAT ENAMELS FOR CAST-IRON.—H. F. Staley (*J. Amer. Cer. Soc.*, **1**, 98, 1918). The author found that in cast-iron enamels the potash felspar, flint and clay may be substituted for one another without changing the fusibility of the enamel, the ratio being 100 felspar : 66⅔ flint : 40 clay. Assuming flint to be substituted in these proportions for all the clay and felspar of a ground coat formula, and reducing to 1,000 pounds of melted batch, a number is obtained indicating the pounds of flint that would have been used for 1,000 pounds of the ground coat melted, if flint were the only refractory used. This number is called the "flint equivalent" of the formula, and gives a fair indication of its refractoriness, for the influence of ordinary variations in the relative amounts of fluxing oxides is negligible in comparison. Recipes for 7 ground coats are given, of which one is refractory (flint equivalent 869), another is quite fusible (flint equivalent 658), and the flint equivalents of the remaining five (supposed to be well adapted for ordinary enamelled ironwares) only vary from 736 to 732.

SOME PHENOMENA IN GLAZE REDUCTION.—H. B. Henderson (*J. Amer. Cer. Soc.*, **1**, 148, 1918). Report of investigation of salt-glazed sewer-pipes and fire flashed bricks. Both the salt glaze and the surfaces of fire flashed bricks were found to contain crystalline matter. The red to yellow crystals, to which the colour of the product is due, represent ferric oxide or other modifications of iron oxide. It is probable that the colour of the crystals is due both to a variable iron content (derived from the clay or kiln gases) and modifications in the crystalline structure with variations in the temperature and oxygen pressure of the atmosphere. It is also probable that the salt glaze contains carbon, that reducing conditions with the development of free carbon are essential for inducing crystallization, and hence that crystallization starts

in a reducing atmosphere but continues under oxidizing cooling conditions, and finally that re-oxidation largely dissipates the colour effect in flashed clay products.

ACTION OF ACETIC ACID SOLUTIONS ON A SHEET STEEL ENAMEL.—L. J. Frost (*J. Amer. Cer. Soc.*, **1**, 422, 1918). A record of the results of tests made with acid of different strengths.

ENAMELS FOR CAST-IRON.—H. F. Staley (*J. Amer. Cer. Soc.*, **1**, 534, 1918). An illustrated account of the preparation and application of such enamels.

CONTROL OF THE LUSTRE OF ENAMELS.—H. F. Staley (*J. Amer. Cer. Soc.*, **1**, 640, 1918). The simplest way to overcome the tendency to crystallize is to make the enamel viscous at crystallizing temperatures.

Boric oxide alone forms a very viscous glass at low temperatures, but the viscosity decreases rapidly with rise of temperature. The glass was found to be three times as viscous at 750° C. as at 1,000°; the former temperature is about that at which crystallization takes place in enamels, and the latter is near the maturing temperature of most enamels for cast-iron. The borate glasses of any given base resemble silicate glasses in behaviour and become more viscous as the percentage of boric oxide increases. Increase of the boric oxide in cast-iron enamels increases the viscosity at crystallization temperatures, and thus decreases the tendency to mattness. Material which does not melt or dissolve in the enamel (as most oxides added as opacifiers) makes the enamel more viscous. Decrease of any fluxing oxide, except boric oxide, makes the enamel more viscous, and decrease of fluorides has the same effect. Lead oxide and boric oxide do not, like other fluxes, produce a matt finish when present in the enamel in large amount. The effect of sulphur compounds and index of refraction are also discussed.

ENAMELS FOR CAST-IRON.—H. F. Staley (*J. Amer. Cer. Soc.*, **1**, 703, 1918). It is practically impossible to make a satisfactory enamel for cast-iron unless the boric oxide and lead oxide together exceed a certain minimum, because the amount of the other fluxing oxides that may be added is very small. Boric oxide is always used, and tin oxide enamel compositions fall into three classes: leadless enamels, low lead enamels, and high lead enamels. Formulas are given for seven tin enamels, including examples of each class.

Leadless enamels, owing to the high content of boric oxide and consequent very low coefficient of expansion, would tend to chip—assuming strength, elasticity, etc., to be equal—but in German enamels of this class, the tendency is balanced by comparatively high contents of soda and cryolite. The solvent action of soda on tin oxide necessitates higher content of the latter.

Low lead enamels generally have less than 10 per cent. lead oxide and more than 8 per cent. boric oxide, generally (in America) with considerable zinc oxide.

High lead enamels contain 16 to 25 per cent. of their melted weight as lead oxide, and about 6 per cent. boric oxide is enough to avoid risk of devitrification, though as much as 8 per cent. is often used to give greater strength and elasticity. The amount of any other fluxing oxide rarely exceeds 10 per cent. This is the kind of powdered enamel for cast-iron mostly used in America.

Antimony enamel compositions (without tin oxide) are also referred to and eight formulas are given in which sodium metantimonate or antimony oxide is used as an opacifying agent for enamels for cast-iron. The compositions used again fall into three classes: leadless, low lead, and medium lead. When oxide of antimony is used instead of sodium antimonate the amount of soda is adjusted accordingly.

LEAD SOLUBILITY OF FRITTED GLAZES.—P. Bartel (*Sprech.*, **51**, 25, 31, 35, 39, 43, 1918). For the acetic acid test the finely divided frit must pass

through a sieve of 5,000 meshes per sq. cm. without leaving any residue. Of this material, 2 g. are heated with 100 c.c. of 4 per cent. acetic acid in an Erlenmeyer flask, provided with a reflux condenser, for half-an-hour over wire gauze. After cooling, the contents of the flask are filtered, and in 20 c.c. of the filtrate the dissolved lead is determined by adding a measured quantity of potassium bichromate solution (of which 1 c.c. corresponds to 1 mg. metallic lead). After about 10 minutes the precipitated lead chromate is, by means of a Gooch crucible (or a similar contrivance), separated by absorption of the solution and washed. In the filtrate the excess of potassium bichromate is determined by means of an iodometric process (described). A numerical example is added.

Reference is made to the difference between such finely ground material and the layer of glaze on the ware, and also to the unknown influence of other components such as soda, potash, lime, baryta, magnesia, zinc oxide, alumina, and boric acid, on the solubility of lead in acetic acid.

At the chemical laboratory for *Tonindustrie* in Berlin were produced 817 frits, which were tested; each was designated by a number, a capital letter, and a small letter. The frits were prepared from red lead, soda (or potash, marble, barium carbonate, magnesite, and zinc oxide), washed Zettlitz kaolin, and pure Hohenbocka sand. The following examples illustrate the plan adopted:

3Ab: 183 red lead, 21·2 soda, 25·8 kaolin, 78 sand;
3Ac: 183 red lead, 21·2 soda, 51·6 kaolin, 66 sand;
3Cc: 183 red lead, 21·2 soda, 51·5 kaolin, 96 sand;

3Ab: $0{\cdot}8PbO.0{\cdot}2Na_2O.0{\cdot}1Al_2O_3.1{\cdot}50SiO_2$;
3Ac: $0{\cdot}8PbO.0{\cdot}2Na_2O.0{\cdot}2Al_2O_3.1{\cdot}50SiO_2$;
3Cc: $0{\cdot}8PbO.0{\cdot}2Na_2O.0{\cdot}2Al_2O_3.2{\cdot}00SiO_2$.

In the case of lead silicates ranging from $PbO.1{\cdot}50SiO_2$, $PbO.1{\cdot}75SiO_2$, increasing regularly by $0{\cdot}25SiO_2$ up to $PbO.4{\cdot}00SiO_2$ the lead dissolved by the acetic acid was found to be 10·4 per cent., 6·7, 7·0, 3·3, 3·0, 3·3, 3·3, 5·1, 13·7, 25·8, and 20·5 per cent. respectively. The most resistant pure lead silicate is thus $PbO.2{\cdot}50SiO_2$ with 3·0 per cent. solubility. Three other silicates adjoining in the series have solubility 3·3 per cent.

Another chemist independently obtained for $PbO.1{\cdot}50SiO_2$ a solubility of 31·5 (instead of 10·4), and for $PbO.1{\cdot}75SiO_2$ a solubility of 16·5 per cent. (instead of 6·7). Unfortunately no explanation could be found for these discrepancies. In other cases the results obtained were fully confirmed by several repetitions.

The effect of partial substitution (0·1 to 0·4 molecule) of the lead oxide in lead silicates by soda, potash, lime, baryta, magnesia, and zinc oxide, on the lead solubility was sometimes favourable as regards resistance to 4 per cent. acetic acid.

All the frits were tried with the addition of 0·1 and 0·2 molecule respectively of alumina; these were distinguished by the small letters b and c. Of the frits containing only lead oxide, alumina, and silica, none were completely resistant to acetic acid, and of the other frits the following lost no lead to 4 per cent. acetic acid: $0{\cdot}9PbO.0{\cdot}1Na_2O.0{\cdot}1Al_2O_3.4SiO_2$, $0{\cdot}9PbO.0{\cdot}1Na_2O.0{\cdot}2Al_2O_3.4SiO_2$, $0{\cdot}8PbO.0{\cdot}2Na_2O.0{\cdot}2Al_2O_3.2{\cdot}75SiO_2$, $0{\cdot}7PbO.0{\cdot}3Na_2O.0{\cdot}2Al_2O_3.3{\cdot}25SiO_2$, and $0{\cdot}6PbO.0{\cdot}4Na_2O.0{\cdot}2Al_2O_3$. with 2·25, 2·5, 2·75 and 3·0 SiO_2 respectively (8 frits with soda); $0{\cdot}9PbO.0{\cdot}1K_2O.0{\cdot}1Al_2O_3.4SiO_2$ (1 frit with potash); $0{\cdot}7PbO.0{\cdot}3CaO.0{\cdot}2Al_2O_3.2{\cdot}25$ and $3{\cdot}0SiO_2$, $0{\cdot}6PbO.0{\cdot}4CaO.0{\cdot}2Al_2O_3.2{\cdot}5SiO_2$ (3 frits with lime); $0{\cdot}9PbO.0{\cdot}1BaO.0{\cdot}2Al_2O_3.2{\cdot}75SiO_2$; $0{\cdot}9PbO.0{\cdot}1MgO.0{\cdot}1Al_2O_3.2{\cdot}75SiO_2$, $0{\cdot}8PbO.0{\cdot}2MgO.0{\cdot}2Al_2O_3.1{\cdot}75$ and $2SiO_2$, $0{\cdot}7PbO.0{\cdot}3MgO.0{\cdot}2Al_2O_3.2SiO_2$ $0{\cdot}6PbO.0{\cdot}4MgO.0{\cdot}2Al_2O_3.3{\cdot}25$ and $4SiO_2$ (6 frits with magnesia); $0{\cdot}8PbO.0{\cdot}2ZnO.0{\cdot}2Al_2O_3.2{\cdot}5$ and $2{\cdot}75SiO_2$ (2 frits with zinc oxide).

Of the 817 trial frits, 430 (or 53 per cent.) did not lose more than 2 per cent. of lead. These 430 included 11 lead silicates (some containing alumina), 79 containing soda, 64 containing potash, 74 containing lime, 50 containing baryta, 85 containing magnesia, and 67 containing zinc oxide; the silica ranged from 1·5 to 4·0 SiO_2.

As regards appearance, those which are clear include the lead silicates (also with alumina) up to $3{\cdot}0SiO_2$, soda frits and potash frits up to $2{\cdot}5SiO_2$, lime frits mostly up to $2{\cdot}5SiO_2$, baryta frits mostly up to $1{\cdot}75SiO_2$, magnesia frits and zinc oxide frits much the same as lime frits.

No rule as to lead solubility seems to apply. The simple lead silicate, $PbO.2{\cdot}5SiO_2$, has a lead solubility of 3·0, which is reduced to 2·6, 1·7, 1·3, 1·1 respectively by the substitution of 0·1, 0·2, 0·3, 0·4 molecule soda for lead oxide, or to 2·0 and 0·5 respectively by the simple addition of 0·1 or 0·2 molecule of alumina. The addition of 0·1 or 0·2 molecule of alumina to the soda frits reduces the lead solubility from 1·7 to 1·1 and 0·3, from 1·3 to 0·7 and 0·3, and from 1·1 to 0·8 and 0·0 respectively. In like manner by substitution of 0·1, 0·2, 0·3, and 0·4 lime, the lead solubility changes from 3·0 to 2·6, 12·0, 14·2, and 11·5 respectively; the last three frits are opaque. The addition of 0·1 or 0·2 molecule alumina changes the lead solubility from 2·6 to 1·1 or 0·3, from 12·0 to 1·4 or 0·3, from 14·2 to 1·2 or 0·3, and from 11·5 to 0·9 or 0·0 respectively.

Determinations of viscosity and softening points (or melting points) of most of the frits were also made. Tests for melting point were also made of trial frits to which $0{\cdot}25$ molecule B_2O_3 had been added. The frits containing boric oxide without alumina generally showed a very high lead solubility; addition of 0·1 molecule alumina generally reduced it, and addition of 0·2 molecule in part reduced it very considerably, especially with frits high in silica. The frits with potash behaved in a striking manner; with 0·1 molecule K_2O and a medium content of silica (2·0 to 3·5 molecules) the lead solubility in the frit containing alumina was about as high as, and sometimes even higher than, in the frits without alumina, reduction taking place only with 3·75 and 4·0 molecules silica. Increasing quantities (0·2 to 0·4 molecule) of alkalies, alkaline earths, and zinc oxide, in frits containing boric oxide generally lowered the lead solubility, but sometimes the reverse. In frits containing potash, an increase of the latter causes increased lead solubility. In frits containing lime but no alumina, with 3·5 or more silica the lead solubility is reduced.

With most of the frits containing boric oxide but no alumina, and with $2SiO_2$, the lead solubility increased with increase in alkalies, alkaline earths, and zinc oxide; frits with boric oxide have not been found which show no lead solubility, although the lead solubility is only small with some, particularly with those containing a larger content of silica. Of the 560 frits containing boric oxide, only 48 (or 8·6 per cent.) have less than 2 per cent. lead solubility; possibly frits with boric oxide but more than 0·2 molecule alumina might give no lead solubility. Frits containing boric oxide showed lead solubility ranging from 0·9 to 21 per cent., but mostly about 1 to 3 per cent.; that which showed 0·9 per cent. had the formula $0{\cdot}8PbO.0{\cdot}2Na_2O.0{\cdot}2Al_2O_3.2{\cdot}75SiO_2.0{\cdot}25B_2O_3$, and that with 21 per cent. was $0{\cdot}9PbO.0{\cdot}1Na_2O.0{\cdot}1Al_2O_3.4SiO_2.0{\cdot}25B_2O_3$.

Several other series of trials had been projected, including a series to determine the influence of zinc oxide on lead solubility, but it was not found possible to carry them out.

GALENA IN FINE CERAMIC GLAZES.—H. Marquardt (*Sprech.*, **51**, 82, 1918). A brief account of an investigation, the result of which is an earnest recommendation to let the galena be smelted, and to use lead oxide as hitherto for glazes.

PHOSPHORIC ACID IN GLASSES AND GLAZES.—H. Fritz (*Sprech.*, **51**, 149, 153, 157, 1918). Report of trials. A. Bases were (a) $0{\cdot}1K_2O.0{\cdot}1CaO.0{\cdot}8PbO$, (b) $0{\cdot}3K_2O.0{\cdot}4Na_2O.0{\cdot}1CaO.0{\cdot}2PbO$, (c) $0{\cdot}2K_2O.0{\cdot}2Na_2O.0{\cdot}2CaO.0{\cdot}4PbO$. The phosphoric acid and alumina were: I, $1P_2O_5$; II, $0{\cdot}1Al_2O_3.1P_2O_5$; III, $2P_2O_5$; IV, $0{\cdot}2Al_2O_3.2P_2O_5$; V, $3P_2O_5$; VI, $0{\cdot}3Al_2O_3.3P_2O_5$; VII, $0{\cdot}15Al_2O_3.3P_2O_5$. From these were made up 21 glaze formulæ and mixtures represented by aI, aII, aIII, aIV, aV, aVI, aVII, bI, bII, bIII, bIV, bV, bVI, bVII, cI, cII, cIII, cIV, cV, cVI, cVII. These mixtures were filled in clay crucibles and fired in a muffle. Cone 03a should have melted, but was not, and it appeared that it had been attacked by some volatilized phosphorus pentoxide,

which evidently displaced silica. The first 15 and the last one formed bright glasses, especially most of those with high proportions of lead (a and c with I, II, and III). Some of these glasses attracted water from the air and became sticky, including those with 2 or $3P_2O_5$ but no alumina, and with $3P_2O_5$ and little alumina (cVII). Glasses aI, cI, aII, cII, aIV, cIV, and bIV were so strongly refractory that they might be useful for artificial gems or for special optical glasses.

The glasses were finely ground and applied to a body of given composition (fired at cone 4a), and the trials fired in a muffle at cone 03a. All but four were crazed, eight were more or less matt, and only aIV was neither. Many of the glazes, though partly white, showed numerous brownish grey spots and specks.

In further trials phosphates of barium, lead, calcium, potassium, sodium, and zinc were used, with interesting results. Owing to the cost of the materials, such glasses and glazes could only be used for special purposes.

GLAZES WITHOUT LEAD OR BORIC ACID.—W. Pukall (*Sprech.*, **51**, 167, 171, 1918). A general discussion of the question, the body also being considered. It is suggested that modification of the body is desirable, with a view to lowering the firing temperature (cone 7). The body of approximately normal composition, 49 clay substance, 45 quartz, and 6 felspar (made up of 25·20 parts by weight Löthain-Meissen clay, 32·94 Brachwitz kaolin, 36·41 quartz, 5·45 felspar) is biscuited at cone 9. Trials were made by adding different proportions of washed chalk, biscuit firing at a strong red heat, then glazing and glost firing in a muffle at cone 7. The desired result was attained by addition of between 10 and 20 per cent. of washed chalk (or, better, marble when feasible) to the body. The glaze applied, also well established as a stoneware glaze, flows out well even before cone 4, corresponds to the formula $0{\cdot}2K_2O.0{\cdot}7CaO.0{\cdot}1MgO.0{\cdot}4Al_2O_3.3{\cdot}5SiO_2$, and is made from 111·2 parts by weight felspar, 51·6 Zettlitz kaolin, 114·0 Hohenbocka sand, 70·0 marble, and 8·4 magnesite. This composition may be varied according to circumstances. The glazing may be done on the unfired body if desired, and the ware fired once only, when the ware is thick enough. As regards decoration, many underglaze colours are durable at cone 7; they are much less affected by the proposed glaze than by any frit glaze. The advantages claimed for easily fusible felspar glazes are: exclusion of raw materials difficult to obtain and expensive (zinc oxide, soda, nitre, potash, lead oxide, boric acid compounds, etc.); avoidance of the glaze fritting process and all difficulties depending on it; simplification of the production of large pieces by single firing; economy of coal through firing the felspar earthenware to cone 7 instead of to cone 9; regained liberty in decision and independence of the raw materials; greater purity of the ware. The disadvantages are: small changes in the preparation of the mass (more like stoneware); partial introduction of treatment of vessels as in production of porcelain (lower biscuit firing and higher glost firing); small changes in the saggars, and in setting; trifling changes in the kind of decoration.

ANTIMONY OXIDE AS AN OPACIFIER IN CAST-IRON ENAMELS.—J. B. Shaw (*J. Amer. Cer. Soc.*, **1**, 502, 1918). Reports results of numerous experiments. It is concluded that antimony oxide can be successfully used if great care is taken in proportioning the raw materials, in mixing, and in smelting, providing only the purest white antimony oxide be used, along with a little fluorspar (not more than 5 per cent. of the raw batch), and with oxidizing conditions maintained (by using plenty of nitre) during smelting, and if the colour be controlled by adding ferric oxide, manganese dioxide, and lead oxide. Cryolite is unsatisfactory as a flux or opacifier in antimony enamels, but small quantities (up to 3 per cent.) will aid in producing a good colour without otherwise causing trouble.

GLAZING IN THE CASTING AND STAMPING PROCESSES.—A. Herborth (*Ker. Rund.*, **26**, 183, 1918). A discussion of L. Wunder's paper

mentioned in the preceding abstract, including references to several experiences of the author.

NEW METHOD OF GLAZING CAST ARTICLES.—L. Wunder (*Ker. Rund.*, **26**, 127, 131, 1918). See abstract in section IV headed "Preventing Distortion of Cast Porcelain Figures, etc."

PHOSPHORIC ACID GLAZES AND GLASSES.—H. Fritz (*Ker. Rund.*, **26**, 195, 201, 205, 1918). See abstract of same paper from *Sprech.*, **51**, 149, 153, 157, 1918).

LEAD SOLUBILITY OF FRITTED GLAZES.—P. Bartel (*Ker. Rund.*, **26**, 247, 251, 1918). See abstract from *Sprech.*, **51**, 25, 31, 35, 39, 43, 1918.

TALC FOR PORCELAIN GLAZE.—S. Kaneshima (*J. Chem. Ind.*, Tokyo, **20**, 850, 1917). Comparative tests were made of glazes consisting of felspar, Gairome clay, and silica, with talc or precipitated calcium carbonate, the MgO replacing CaO in equivalent proportions. The talc (from South Manchuria) consisted of 65·32 silica, 32·47 magnesia, 0·72 lime, 0·12 alumina and ferric oxide. The talc glazes were found to be more fusible than the calcium carbonate glazes but less liable to become overfused, and also less liable to have bubbles in the finished glaze. Talc glaze usually showed more lustre than calcium carbonate glaze, but underglaze colours were less brilliant.

VII.—COLOURS & DECORATIVE PROCESSES.

LIGHT PATCHES ON GREEN GLAZED TILES.—C. E. Ramsden (*Pot. Gaz.*, **42**, 39, 1917). See also TRANS., **17**, 202, 1918.

EFFECT OF MAGNESIAN GLAZES ON UNDERGLAZE COLOURS.—C. P. Shah (*Pot. Gaz.*, **42**, 977, 1917). See TRANS., **17**, 106, 1918.

CHROME-TIN PINK.—E. W. T. Mayer (*Pot. Gaz.*, **42**, 1,184, 1917). See also TRANS., **17**, 104, 1918.

POLYCHROME DECORATION OF TERRA-COTTA WITH SOLUBLE METALLIC SALTS.—H. Wilson (*J. Amer. Cer. Soc.*, **1**, 353, 1918). Has reference to the use of soluble nitrates and chlorides, etc. The terra-cotta piece is sprayed with a single glaze and the various sclutions painted on as desired; the liquid quickly soaks into the dry glaze, so no heating is required to set the glycerine present in the solutions. The ware is burned in the usual way in a single firing. Formulæ are given for various colours, and also for glazes, etc. Good blues (from a very light sky-blue to deep blue) are very easily obtained with cobalt sulphate. Good light pinks can be produced with mixtures of tin chloride and chromium acetate. Other more or less reliable colours obtainable in the glazes are browns, greys, greens, etc.

COLOURS PRODUCED BY SOLUBLE METALLIC SALTS.—P. G. Larkin (*J. Amer. Cer. Soc.*, **1**, 429, 1918). The application of these colours on matt glazes gives on the whole the best results and the greatest colour range, producing colours of cleaner shade than those possessed by either the full-glazed or standard finish terra-cotta.

Uniformity of colour may be obtained over large areas by spraying the solution, but this is successful only in the case of flat surfaced pieces, where it would probably be as economical to use a glaze coloured by metallic oxides.

Standard solutions were made by mixing 75 parts water and 25 parts by volume glycerine, and dissolving in 100 c.c. of this 50 grammes of nitrate of iron (ferric), uranium, manganese, nickel, or copper, or chloride of cobalt, tin, or zinc; or 25 g. chromium nitrate with 2 g. zinc chloride, adding 10 per cent. wood alcohol in each case. A number of blends are also given. Aniline dyes dissolved in alcohol were added for distinction.

SHARP FIRE COLOUR FLUXES.—T. Hertwig (*Sprech.*, **51**, 79, 1918). To prevent the action of the covering glaze on metallic oxides, the painting is done on the glaze (raw or fired). The oxides are thereby embedded in the fluxes or absorbed in alumina or quartz, etc., according as the fluxes or alumina, quartz, etc., cause the shade of colour. It is quite indifferent whether the embedding of the metal in flux or in body poor in flux results, the latter being then simply glazed over. Thus only it becomes possible to use coverings which render feasible new tinges of colour and an extensive freedom with the work.

The author found that matt glazes rich in clay with low quartz have the property of porous glazes. In consequence of this metals can produce lustre in them and in cooling assume their forms of oxidation, being thus not combined as silicates. Iron as silicate is brown; it is now not formed as such, but is oxidized and becomes blood-red, which fine colour can be acquired in this way. If chromium or manganese is combined with the alumina, the pink becomes red and increases that of iron oxide to a fiery blood-red, especially in combination with concentrated manganese red. Uranium develops in such glasses its yellow oxide, as also does vanadium. Vanadium, tungsten, and molybdenum with formation of their respective acids give orange yellow. Chrome-aluminas develop on the glaze purple, mixed with red and blue matt glazes, marone and many other shades. Evidently no glassy glaze must be used for mixing. In the palette is now wanting only cinnabar red, yet it may be assumed on the basis of recent observations that even this unique colour can be produced with red zirconium silicate.

If the colour fluxes are strengthened with much body colour they are also employable for steel plate printing. If some sugar be added and fired porcelain be decorated, printed outlines can be filled with the colour fluxes. In this way may be obtained a really durable decoration for porcelain vessels and a valuable substitute for underglaze painting, which always gives comparatively much waste.

The palette of coloured blue masses is developed almost to completeness, from the palest light blue to the deepest violet blue. A fine orange is obtained from $0{\cdot}8FeO.0{\cdot}2K_2O.0{\cdot}7Al_2O_3.0{\cdot}3B_2O_3.4ZrO_2.2TiO_2.2P_2O_5$, calcined at cone 13. The mixture is made of 3 g. of this body, 6·6 g. of glaze, 0·5 g. anhydrous borax, and 0·5 g. zinc oxide, the glaze being $0{\cdot}758CaO.0{\cdot}242K_2O.0{\cdot}59Al_2O_3.6{\cdot}5SiO_2$.

Every metallic oxide can be melted in such a flux, so that by mixing with glazes a variety of shades may be produced. Manganese pink, consisting of $0{\cdot}257MnO.0{\cdot}753K_2O.2Al_2O_37SiO_2.0{\cdot}135P_2O_5$, embedded in a glass rich in clay, yielded a splendid rose flux, and mixed with iron red, a cherry red. The colour fluxes can be painted on the raw or burned glazes, or laid on with round stamps.

Many metals give unusual tints, as manganese a peculiar green (instead of yellow), nickel blue and green (instead of brown), tungsten foxy red, orange and blue, and molybdenum orange (instead of black).

A manganese green is produced by dissolving Mn_2O_3 in boiling H_3PO_4, then mixing in aluminium hydroxide, neutralizing with $BaCO_3$, and washing the peach blossom red precipitate with hot water.

In blowing the colours (with stencils) it is recommended to use 1 to 4 layers according to depth of colour required, each layer being dried well before applying another. The colour fluxes may also in part, particularly green, be used under the glaze.

VIII.—COSTS, MANAGEMENT, ORGANIZATION. COMMERCIAL REPORTS.

FIREPROOF CLAYWARES AND THEIR MARKETS.—B. (*Tonwar. Ofen. Ztg.*, **41**, 65, 82, 1917). Relates to vessels used for cooking.

SCIENTIFIC MANAGEMENT IN FIREBRICK WORKS.—C. W. Thomas (*Brick Pot. Tr. J.*, **25**, 153, 1917). See TRANS., **16**, 274, 1917.

CALCULATION OF COSTS IN THE GLASS INDUSTRY.—A. Schiller (*Glas.-Ind.*, **28**, No. 23/24, p. 1, No. 25/26, p. 1, 1917). A general discussion of the question, but with special reference to hollow glassware.

GENERAL ORGANIZATION OF FIREBRICK WORKS.—G. W. Wight (*Brick Pot. Tr. J.*, **25**, 259, 1917). See TRANS., **17**, 74, 1918.

TECHNICAL RESEARCH WORK ON CLAYS.—(*Pot. Gaz.*, **42**, 56, 1917). A review of public correspondence in which F. Gibbons, C. H. Thompson, J. C. Deeley, and C. W. Thomas took part.

RUSSIAN ELECTRICAL PORCELAIN.—(*Pot. Gaz.*, **42**, 70, 1917). An account of a porcelain factory established at Riga.

UNESTIMATED LOSSES IN POTTERY MANUFACTURE.—A. Leese (*Pot. Gaz.*, **42**, 595, 1917). The retiring President's address. See TRANS., **16**, 189, 1917.

SCIENTIFIC MANAGEMENT OF FIREBRICK WORKS.—C. W. Thomas (*Pot. Gaz.*, **42**, 680, 1917). See TRANS., **16**, 274, 1917.

COSTS.—C. H. Scovell (*Brick*, **51**, 579, 1917). A general discussion of the question of costs, especially in connection with clay industries, reference being made to the analysis and distribution of overhead expense or burden, labour, and material respectively. It is claimed that a frank comparison of costs on typical items would kill unhealthy competition.

RELATION BETWEEN PERPETUAL INVENTORY VALUE AND APPRAISAL VALUE.—(*Cassier's Eng. M.*, **51**, 287, 1917). A discussion of depreciation, costs, etc., including an American table of Standard depreciation rates. From a paper read by C. Piez before the American Society of Mechanical Engineers.

DEPRECIATION.—(*Cassier's Eng. M.*, **51**, 216, 1917). A review of a paper by F. Gill and W. W. Cook, read before the Institution of Electrical Engineers, London.

FOUNDRY COSTS.—C. H. Scovell (*Cassier's Eng. M.*, **51**, 197, 1917). A short description of a system of production and accounting for ascertaining the exact prices of castings.

INCREASING PRODUCTION AND LOWERING COST.—C. V. Carpenter (*Cassier's Eng. M.*, **51**, 108, 188, 1917). A general discussion of the question, with a reference to a particular case in which a large manufacturing concern, by the application of efficiency methods, increased its output more than four-fold in four months, while only doubling its hands, and without causing the slightest disturbance.

POWER-PLANT EFFICIENCY.—V. J. Azbe (*Cassier's Eng. M.*, **51**, 339, 1917). A paper read before the American Society of Mechanical Engineers, dealing mainly with the improvements possible in plants that supply power for small factories, office buildings, and various institutions, which are the most prevalent and the most uneconomical.

COST OF POWER.—(*Cassier's Eng. M.*, **51**, 62, 1917). A review of a report by C. E. Stromeyer.

PRINCIPLES OF INDUSTRIAL ORGANIZATION.—H. N. Stronck (*Cassier's Eng. M.*, **51**, 402, 1917). An article dealing with the elementary principles.

PRODUCTIVE CAPACITY A MEASURE OF MANAGEMENT.—(*Cassier's Eng. M.*, **51**, 285, 1917). A short discussion of the subject from a paper by H. L. Gantt read before the American Society of Mechanical Engineers. Stress is laid on the expense associated with machinery which is not in use.

SCIENTIFIC *versus* INTUITIVE ADMINISTRATION.—D. T. Farnham (*Cassier's Eng M.*, **51**, 268, 1917). An article from "Industrial Management." The author shows how, by the indications given by curves, the tendencies which threaten profits can be remedied.

SYNTHETIC COSTS.—J. K. Mason (*Cassier's Eng. M.*, **51**, 58, 1917). An article in which the author insists on the importance of keeping accurate cost records showing the kind of expense incurred, the purpose for which it is incurred, and the process or operation which justifies the expenditure.

WORKS ORGANIZATION. PARTS II AND III.—E. L. Orde and G. H. Tweddell (*Cassier's Eng. M.*, **51**, 27, 416, 1917). The first part (on manufacturing organization) was published in vol. 50, p. 411. Part II deals with the financial organization, and especially costing and estimating. Part III deals with the selling organization. A review of all three parts appears on p. 416.

BASIS OF MANUFACTURING COSTS.—H. L. Gantt (*Cassier's Eng. M.*, **52**, 269, 1917). The author suggests a separation of expense items into those that do and those that do not contribute to production, the latter being concerned in determining factory costs. He advocates the machine-hour rate method of applying indirect expense wherever possible, and a uniform man rate based on man hours where a machine rate cannot be used.

STANDARDIZATION OF COST SYSTEMS FOR FOUNDRIES.—(*Cassier's Eng. M.*, **52**, 435, 1917). A brief account of a plan adopted by the American Foundrymen's Association, providing for the services of experts to subscribers on favourable terms.

CONTROL OF PRODUCTION.—W. E. Freeland (*Cassier's Eng. M.*, **52**, 399, 1917). A description of the production department and the despatching arrangements of the Heald Machine Co. (Worcester, Mass.)

DEPRECIATION OF PLANT AND MACHINERY.—(*Cassier's Eng. M.*, **52**, 287, 1917). A discussion of the question, with special reference to Inland Revenue allowances.

EFFICIENCY REWARD.—G. H. Shepard (*Cassier's Eng. M.*, **52**, 35, 1917). An article from *Industrial Management* dealing with the relation of bonus payment to time rate and piece rate under various conditions.

FATIGUE AND ITS ELIMINATION.—(*Cassier's Eng. M.*, **52**, 219, 1917). An editorial article partly based on the two following articles.

SOME ASPECTS OF INDUSTRIAL FATIGUE.—H. J. Spooner (*Cassier's Eng. M.*, **52**, 223, 1917). A discussion of the factors influencing fatigue, etc. Hints are given for avoidance of unnecessary fatigue.

INDUSTRIAL FATIGUE.—(*Cassier's Eng. M.*, **52**, 236, 1917). Hints on the practical side of fatigue elimination, based on the study of F. B. and L. M. Gilbreth's work.

THREE INDUSTRIAL PROBLEMS.—C. F. Holmboe (*Cassier's Eng. M.*, **52**, 5, 1917). A discussion of points concerning the production cost with relation to the output, the work efficiency, and consideration of the workers' comfort when designing new works.

RELATION OF WAGES TO PRIME COSTS.—F. T. Clapham (*Cassier's Eng. M.*, **52**, 346, 1917). A discussion of such problems as how to increase production, etc.

ROWAN PREMIUM BONUS SYSTEM.—(*Cassier's Eng. M.*, **52**, 367, 1917). An article based on W. R. Thomson's book, "The Premium Bonus System."

SYSTEMS OF WAGES.—(*Cassier's Eng. M.*, **52**, 363, 1917). An editorial article discussing the three chief methods of paying wages, viz., Time Rate, Piece Work, and Premium Bonus, the latter being a combination of the other two.

TIME RECORDS.—(*Cassier's Eng. M.*, **52**, 259, 1917). A discussion of their importance in costing, based on A. H. Gledhill's book on "Practical Costing."

COST ACCOUNTING IN THE BRICK BUSINESS.—H. W. Conway (*Brick*, **54**, 876, 1919). A discussion of the various items, with illustrative examples.

PRICE AND PROFIT.—M. Roesler (*Sprech.*, **51**, 161, 1918). A general discussion of the question, but with more particular reference to hard porcelain.

FUTURE PROBLEMS OF THE CERAMIC INDUSTRY.—C. Tostmann (*Sprech.*, **51**, 193, 199, 1918). A general review, but with particular reference to the coming competition with Japan, and the means of meeting it.

SCIENTIFIC WORK IN CERAMICS.—R. Rieke (*Sprech.*, **51**, 206, 1918). An address to the Technical Section of the Association of Ceramic Works in Germany. Reference is made to improvement of products, cheapening cost of production, etc.

THE PROFITABLENESS OF ROTARY GRATE GENERATORS.—C. Jung (*Sprech.*, **51**, 237, 1918). A discussion of the question, with calculations of costs.

PORCELAIN FROM EASTERN ASIA.—E. Zimmermann (*Ker. Rund.*, **26**, 37, 43, 1918). Relates to the export of porcelain from China and Japan.

THE BELGIAN GLASS INDUSTRY BEFORE THE WAR.—G. G. (*Ker. Rund.*, **26**, 137, 1918). Statistics of production, etc.

FUTURE PROBLEMS OF THE GERMAN CERAMIC INDUSTRY.—R. Rieke (*Ker. Rund.*, **26**, 93, 97, 1918). A general survey of the situation. The author specifies the following points as meriting serious consideration: substitution of native for foreign raw materials, improvement of quality of wares, lowering costs of production, and creation of new fields of employment. He suggests the establishment of a ceramic research institute.

FUTURE PROBLEMS OF THE CERAMIC INDUSTRY.—C. Tostmann (*Ker. Rund.*, **26**, 143, 147, 1918). See abstract from *Sprech.*, **51**, 193, 199, 1918.

SCIENTIFIC WORK IN CERAMICS.—R. Rieke (*Ker. Rund.*, **26**, 151, 159, 1918). See abstract from *Sprech.*, **51**, 206, 1918.

FUTURE PROBLEMS OF THE GERMAN CERAMIC INDUSTRY.—M. Roesler (*Ker. Rund.*, **26**, 164, 1918). A general discussion, with suggestions as to advantageous employment of waste materials (ashes, slags, old moulds, etc.).

PRICE AND PROFIT.—M. Roesler (*Ker. Rund.*, **26**, 179, 1918). See abstract from *Sprech.*, **51**, 161, 1918.

FACTORY BOOKKEEPING AND SUPERINTENDENCE IN THE CERAMIC INDUSTRY.—F. Wagner (*Ker. Rund.*, **26**, 225, 230, 1918). A summary review.

COSTING AS APPLIED TO GAS UNDERTAKINGS.—E. Cooke (*Gas World*, **69**, 253, 1918). Report of lecture by the accountant to the Birmingham Gas Department. An outline is given of the method followed at Birmingham.

COSTING AS APPLIED TO GAS UNDERTAKINGS.—E. Cooke (*Gas J.*, **144**, 260, 1918). Report of same lecture as the preceding.

RESEARCH ORGANISATIONS.—(C.R.O. No. 1). At a Conference of Research Organisations held at the Board of Education's Offices on the 29th July, 1919, several important topics were brought forward for discussion, and many interesting points were brought out. At the time nine Research Organisations were in being, eight had been approved by the Department of Scientific and Industrial Research and only awaited the license of the Board of Trade, and another dozen were under discussion between the industries and the Department. The principal subjects discussed at the conference were: (1) the formation of a Records Bureau, (2) conditions of employment of research workers by Research Associations, (3) co-operation amongst Research Associations for the study of accessory materials or equipment, and (4) subscriptions to Research Associations.

(1) As regards records, the Records Bureau is to be organised in two sections, a confidential section and a non-confidential section. The ownership in scientific results (by Research Associations) is that of the members of the Association, the Association holding that property in trust for its members. Research Organisations, when forwarding information to the Department, will indicate which parts they consider confidential, and the confidential section of the Bureau will communicate such informtaion to nobody at all without agreement with the body or person that sends it. In cases where confidential information may be very valuable to another Research Association the Department will be prepared to act as intermediary for the transference of the information if agreeable to the sender or senders. The Department has an annual vote in Parliament, as well as the million fund which is available for Research Associations, and it is hoped the Bureau will be sustained by the annual vote and not by the million fund. It is not intended that the Associations shall be relieved from collecting their own information and from having their own libraries of periodicals and books for reference to original papers, etc. At the same time the Department through the Records Bureau would be prepared to do whatever it could to assist Research Associations to get a sight of rare publications, and within reasonable limits to get extracts from documents that happen to be in London, for the benefit of an Association with distant headquarters. The Bureau will naturally get to know of new sources of information, and the attention of the Associations will be directed to these new sources.

Among suggestions the carrying out of which is presumably not practicable, at least not yet, was one for the collection (within limits) of incidental data often obtained in the course of research but having no direct connection with the main object, another for the provision of facilities for personal intercourse between those engaged in similar research work.

(2) The conditions of employment of research workers gave rise to an interesting discussion, but, though a feeling seemed to prevail that the workers should be adequately rewarded, the differences in the conditions of different industries made it difficult to arrive at any definite general conclusion. It was suggested that perhaps another conference for discussion of this question might lead to something more definite in the light of further experience.

(3) With reference to co-operation for the study of accessory materials or equipment, it was mentioned that scientific progress made at the instance of aircraft workers was found to be of value to furniture makers, piano-builders, manufacturers of ply-wood, shipbuilders, makers of felt hats, the woollen textile industries, paper makers, and many others, in connection with the use of adhesives and cements. For an expenditure of about £1,000 in one year some astonishing results have been obtained, including the discovery of new sources of protein to make up the shortage of glue, the economical treatment of casein, etc.

The personal suggestions made included (*a*) appointment of Joint Committees, consisting of representatives of different Associations, to deal with specific problems, the financial obligations being adjusted by agreement between the Associations, (*b*) the mutual appointment of several representatives on each of the Associations in a group with overlapping interests, and settlement by discussion which Association shall carry out any particular research,

(*c*) a Conference of the Associations concerned to discuss any problem that arises, (*d*) appointment of a Joint Committee of all the Research Associations having a common interest in certain subjects (as tropical agriculture, seed growing, seed for sugar, seed for cotton, etc.).

(4) The subscriptions to Research Associations gave rise to much discussion. The methods suggested by the Department (in pamphlet marked "Research Associations. 4. The Method of Subscriptions to Research Association.") are by a levy based on total capital employed, on average annual profits over a definite period, on the annual wage bill, on the number of persons employed, on the volume of the output, on the value of the output, or on the amount of plant. In the case of the Refractories Research Association, it had been decided after full consideration to raise subscriptions upon a voluntary basis, serious objections being met with as regards disclosures in connection with the other proposals, and difficulties arising also in the attempt to include consumers in the Association. The glass industry has for similar reasons adopted the same plan as the Refractories Research. Most of the Research Associations already formed have adopted some kind of levy as a basis for their subscriptions.

X.—GLASS

TECHNIQUE OF ETCHING IN GLASS DECORATION.—F. Huth (*Glash.*, **47**, 2, 1917). A brief notice of several methods of procedure.

INFLUENCE OF DIFFERENT KINDS OF COAL.—Loeser and F. Styzynski (*Glash.*, **47**, 161, 163, 178, 1917). A discussion of the influence of different kinds of coal on the production of temperature in the furnace. On p. 163 is a contribution by Styzynski, and on p. 178 some errata in Loeser's article are corrected.

THE MELTING OF GLASS BATCHES.—H. Kühl (*Glash.*, **47**, 257, 1917). A discussion of the sources of loss in the melting of glass mixtures containing sodium sulphate (instead of sodium carbonate), as was compulsory during the war. Sometimes broken plate glass was added. The composition of several ordinary mixtures is given.

MACHINES FOR BLOWING WINDOW GLASS.—(*Glash.*, **47**, 402, 1917). A description of contrivances which are claimed to be economical in use.

GLASS COLOURING AND DECOLORIZING MATERIALS.—(*Glas.-Ind.*, **28**, No. 1/2, p. 2, 1917). A brief discussion of the effects of the oxides of tin, uranium, antimony, silver, manganese, nickel, cobalt, and arsenic, and also the effects of carbonaceous matter, sulphur, and selenium.

JENA GLASS.—E. B. (*Glas.-Ind.*, **28**, No. 7/8, p. 2, 1917). Relates to the characteristic differences between Jena normal and Fiolax glass. Fiolax is a trade name for a glass with minimum alkali content, and therefore specially suitable for producing phials. It appears to consist of silica, boric acid, alumina, and lime, and is harder, more difficultly fusible, and more resistant than normal glass. In mass Fiolax glass has a light sea-green tinge, which colours it greenish-yellow. Tests made by the author indicated that the Fiolax glass gave up to reagents a trifling amount of alkali compared with that from the normal glass.

THE MELTING OF GLASS.—(*Glas.-Ind.*, **28**, No. 13/14, p. 1, 1917). A general review of the operation, with special references to glass galls and various defects in melting.

SILVERING GLASSWARE.—W. Hannich (*Glas.-Ind.*, **28**, No. 21/22, p. 1, 1917). The necessary operations are described, with special details of the Browning and Martin methods.

NEW PROCESS FOR SEAMLESS GLASS VESSELS.—(*Glas.-Ind.*, **28**, No. 25/26, p. 2, 1917). An illustrated description of a German invention for avoiding vertical seams in particular. It is patented by the Adler Glass Works.

SULPHATE IN THE GLASS INDUSTRY.—H. Schnurpfeil (*Glas.-Ind.*, **28**, No. 29/30, p. 9, 1917). A discussion of the importance of sulphate during the war, when soda and potash were under severe restrictions.

MOULDS FOR GLASS.—R. Sachsze (*Glas.-Ind.*, **28**, No. 31/32, p. 17, 1917). Taken (with illustrations) from the second edition of a book on Chemical Technology by the author.

MANUFACTURE OF GLASS EYES.—E. Schwarzbach (*Glas.-Ind.*, **28**, No. 33/34, p. 25, 1917). Although the merit of having first produced artificial eyes from enamel is assigned to Boisseneau at Paris, it is claimed that Müller at Lauscha, in 1850, had already entered the market with artificial glass eyes and excited general sensation with the very successful imitations. A general description of the method of manufacture is given.

THE NEW TEMPAX GLASS.—F. L. (*Glas.-Ind.*, **28**, No. 33/34, p. 26, 1917). A variety made at Jena, which is said to be capable of substituting quartz glass in many cases.

PRODUCTION OF GLASS BUTTONS.—W. Hannich (*Glas.-Ind.*, **28**, No. 35/36, etc., pp. 33, 41, 57, 1917). A general account of the processes of manufacture.

THE MELTING OF GLASS.—J. B. (*Glas.-Ind.*, **28**, No. 44/45, p. 73, 1917). A discussion of the most advantageous means, having regard to the scarcity of coal.

AUTOMATIC ARRANGEMENT FOR BOTTLES.—(*Glas.-Ind.*, **28**, No. 46/47, p. 81, 1917). A description of an appliance suitable for one-litre bottles.

GLASS POTS LOSING HEAT.—(*Glas.-Ind.*, **28**, No. 48/49 and 50/52, pp. 89, 97, 1917). A discussion of the causes and possible means of prevention.

BRITISH GLASS SANDS.—P. G. H. Boswell (*Pot. Gaz.*, **42**, 188, 1917). Report of paper read before the Society of Glass Technology. See also TRANS., **16**, Abs. 117, 1917.

BRITISH GLASS SANDS.—C. J. Peddle (*Pot. Gaz.*, **42**, 188, 1917). Report of paper read before Society of Glass Technology. See also TRANS., **16**, Abs. 117, 1917.

ANNEALING OF GLASS.—F. Twyman (*Pot. Gaz.*, **42**, 261, 1917). Report of paper read before Society of Glass Technology. See also TRANS., **16**, Abs. 117, 1917.

ANNEALING.—S. English (*Pot. Gaz.*, **42**, 261, 1917). Report of paper read before Society of Glass Technology. Refers to an investigation of annealing phenomena of several different kinds of glass. Some numerical results are given.

GLASS FURNACES ON THE CONTINENT.—T. Teisen (*Pot. Gaz.*, **42**, 349, 1917). Report of paper read before Society of Glass Technology. See also TRANS., **16**, Abs. 118, 1917.

OPALESCENCE FROM IMPURITIES.—J. D. Cauwood and W. E. S. Turner (*Pot. Gaz.*, **42**, 349, 1917). Report of paper read before Society of Glass Technology. See also TRANS., **16**, Abs., 116, 1917.

MACHINERY AND LABOUR-SAVING DEVICES IN THE GLASS FACTORY.—(*Pot. Gaz.*, **42**, 497, 1917). A discussion at a meeting of the Society of Glass Technology.

REFRACTORY MATERIALS FOR GLASS MANUFACTURE.—W. G. Fearnsides, J. H. Davidson, W. Rosenhain (*Pot. Gaz.*, **42**, 686, 1917). Report of papers read before Society of Glass Technology. See also TRANS., **16**, Abs. 118, 119, 1917.

ACTION OF CHEMICAL AND PHYSICAL AGENTS ON SCIENTIFIC GLASSWARE.—J. D. Cauwood, S. English, and W. E. S. Turner (*Pot. Gaz.*, **42**, 861, 1917). Report of paper read before Society of Glass Technology. See also TRANS., **17**, Abs. 164, 1918.

GLASS POTS—WASTE POTTERY BISCUIT FOR GROG.—(*Brick*, **51**, 951, 1917). The U.S. Bureau of Standards in a circular letter recommended the whiteware biscuit waste as well suited for the grog of glass pots, especially those used for melting optical glass.

GLASS POTS BY CASTING.—F. H. Riddle (*Brick*, **51**, 1,129, 1917). It is claimed that open top glass pots can be made more quickly and more cheaply than by hand, and at least as dense.

SCIENTIFIC GLASSWARE.—M. W. Travers (*J. Soc. Chem. Ind.*, **37**, 235T, 1918). An account of the investigation of various problems connected with the manufacture of glass, and more especially glass for various scientific purposes.

SCIENTIFIC GLASSWARE INDUSTRY.—F. W. Branson (*J. Soc. Chem. Ind.*, **37**, 337, 1918). A discussion of some aspects of the subject. Reference is made to a borosilicate glass containing alumina and zinc oxide, and to the desirability of standardizing hollow scientific glassware as to shape, capacity, weight, etc. The graduation and testing of scientific glassware was also alluded to. as well as the importance of annealing such glass.

POTS FOR OPTICAL GLASS.—A. V. Bleininger (*J. Amer. Cer. Soc.*, **1**, 15, 1918). The pots should resist corrosion by the glass, even at the high temperature of the furnace (which may approach 1,475° C.), and should withstand the pressure of the charge and have as low a content of iron oxide as possible. As such pots are only used once the bottom and walls may have minimum thickness. Several mixtures were found satisfactory in working, the most convenient of them being made up of 35 per cent. white ware biscuit (waste) through 10-mesh, 10 pot shell through 10-mesh, 3 felspar, 4 flint, 15 Tennessee ball clay No. 5, 5 Illinois bond clay, and 28 kaolin. The mixed materials are tempered in a wet pan, the mullers being raised about ¼ in. off the bottom of the pan to minimize grinding action. The mixture is then passed through a vertical pug mill and stored as long as possible. The treading of the plastic body has been eliminated as unnecessary. Both open and covered pots are built up by hand in the usual manner. Pots are 34 inches outside diameter, 27 inches high, with bottom 4 inches thick, and wall tapering upwards from 3½ to 2½ inches. Each pot weighs about 500 lb. After drying about four weeks the pots are ready for the furnace.

Some pots are cast, the body composition being 48 per cent. white ware biscuit, 23 plastic bond clay, 24 kaolin, 5 felspar, the slip being compoesd of 80 solids to 20 water; 0·20 per cent. (of the dry weight of the body) of a mixture of equal parts sodium silicate and sodium carbonate is added to make the casting slip. The core of the mould is kept in position during casting, and the slip is delivered through three funnels at equal distances apart round the circumference. Absorption of liquid ceases after about 16 hours, and the core may then be removed, the outer mould being removed after 24 hours. The cast pots have been dried without difficulty in less than three weeks. The thickness of the walls is 2 to 3 inches, so that less time is required in heating up than for the hand-made pots.

These porcelain type pots must be heated to at least 1,400° C.—to vitrify the body—before introducing the charge, otherwise the pots may corrode as

much as ordinary pots. There are two illustrations. See also TRANS., 17, Abs. 166, 1918.

RELATION BETWEEN THE PHYSICAL PROPERTIES AND CHEMICAL COMPOSITION OF GLASS.—E. W. Tillotson (*J. Amer. Cer. Soc.*, 1, 76, 1918). A record of results obtained by means of the refractive index in investigating the systems Na_2O—CaO—SiO_2 and Na_2O—BaO—SiO_2. In the soda lime glasses the author deduced that only one compound was formed from the three oxides, its formula being $2Na_2O.3CaO.7SiO_2$, and ordinary soda lime glasses contain much more soda and silica than this represents. A typical glass rich in alkali, and melting at a low temperature, has approximately the composition $12Na_2O.3CaO.45SiO_2$, and is considered as being made up of a solution of 1 molecule $2Na_2O.3CaO.7SiO_2$, with 10 molecules $Na_2O.2SiO_2$, and 18 molecules SiO_2. The glass rich in lime, and melting at a high temperature, which corresponds to the "normal" formula $Na_2O.CaO.6SiO_2$, is regarded as a solution of 1 molecule $2Na_2O.3CaO.7SiO_2$, with 1 molecule $Na_2O.2SiO_2$, and 9 molecules SiO_2. In the case of the barium glasses, the existence of compounds $Na_2O.BaO.3SiO_2$ and $Na_2O.BaO.4SiO_2$—corresponding to the double salts $Na_2O.2SiO_2$—$BaO.SiO_2$ and $Na_2O.2SiO_2$—$BaO.2SiO_2$ respectively—were indicated, as well as the simple glasses $BaO.SiO_2$ and $BaO.2SiO_2$.

FORMATION OF SEED IN OPTICAL GLASS MELTS.—A. E. Williams (*J. Amer. Cer. Soc.*, 1, 134, 1918). A brief account of observations indicating that gases are evolved during the cooling of the glass at temperatures below 1,200° C. when the viscosity is still quite low. Slow cooling between 1,200° C. and 700° C. increases number and size of the seeds, and rapid chilling prevents their formation. All these glasses contained barium, and the possible formation of BaO_2 has been suggested.

ALABASTER GLASS.—A. Silverman (*J. Amer. Cer. Soc.*, 1, 247, 1918). An account of the manufacture of semi-opaque glasses from early times, with a number of modern recipes. A list of manufacturers is appended, and also an extensive bibliography of both books and articles.

MILKINESS IN OPTICAL GLASS.—C. N. Fenner and J. B. Ferguson (*J. Amer. Cer. Soc.*, 1, 468, 1918). An account of troubles experienced which were eventually traced to the presence of very small amounts of sulphates (and, to a smaller extent, of chlorides), but it was concluded that the direct cause of the milkiness was the separation of clouds of minute crystals of cristobalite.

A discussion by F. Gelstharp appears on p. 559, followed by a reply from the authors.

IDENTIFICATION OF "STONES" IN GLASS.—N. L. Bowen (*J. Amer. Cer. Soc.*, 1, 594, 1918). Stones—that is, foreign particles of a crystalline nature—are classed as pot stones, batch stones, crown drops, and devitrification stones. These classes have distinctive features of structure and texture that are revealed by the petrographic microscope. The crystalline substances in stones can be identified by a determination of their optical properties; they include sillimanite, the forms of silica (quartz, cristobalite, and tridymite), wollastonite and pseudowollastonite, and in special cases barium disilicate.

IRON IN THE FURNACE ATMOSPHERE A SOURCE OF COLOUR IN GLASS.—E. W. Washburn (*J. Amer. Cer. Soc.*, 1, 637, 1918). The author noticed that in some experimental melts of a heavy flint glass worked in an electric furnace there was no colour, whereas the same batch melted in the same type of pot in a gas-fired furnace always had a distinctly greenish colour. The only possible source of the colour seemed to be the atmosphere, and by a special contrivance the presence of iron in the atmosphere was proved. By replacing the iron burners by clay burners, and coating the inner walls of the furnace with kaolin, the colour of heavy flint glasses was distinctly improved.

APPARENT CAUSES OF FAILURE OF LEAD GLASS POTS.—A. F. Gorton (*J. Amer. Cer. Soc.*, **1**, 648, 1918). Examination of the remains of pots show that cracks and corrosion are the chief causes of failure. Cracks result from too rapid heating in the pot arch, from insufficient preheating (probably the chief cause), and from throwing in the glass batch. Corrosion is mostly due to solution of the clay in the fusing alkalies and molten glass, but sometimes to the slagging action of iron on the clay. The rapid corrosion of the clay results from ability to burn the bottom of the pot in the pot arch, and the safest remedy is to burn the pot thoroughly at 2,500° F., applying the heat directly to the bottom. A material more refractory and more resistant to corrosion than fireclay is desirable.

CONDITION OF ARSENIC IN GLASS AND ITS ROLE IN GLASS-MAKING.—E. T. Allen and E. G. Zies (*J. Amer. Cer. Soc.*, **1**, 787, 1918). In all the glasses—plate and optical glasses—tested by the authors, most of the arsenic was present in the pentavalent state, but some was in the trivalent state.

Arsenious oxide is in some cases supposed to whiten the glass. It is also used in fining or removing the small bubbles from glass; it causes the glass to "boil," and the small bubbles are apparently swept out by larger ones. Wood, potatoes, and other substances which give off gas at high temperatures are sometimes used for the same purpose. The chemical behaviour of arsenic in the fining process is little understood. Analytical results obtained with five American glasses seem to indicate that arsenic trioxide is oxidized at low temperatures, and that at a high temperature the product slowly dissociates into oxygen and arsenic trioxide, both of which aid in the fining.

STRENGTH TESTS OF PLAIN AND PROTECTIVE SHEET GLASS.—T. L. Sorey (*J. Amer. Cer. Soc.*, **1**, 801, 1918). The protective glass consists of sheet glass to one side of which a thin sheet of celluloid is firmly attached. In using such glass the celluloid side should be towards the person to be protected.

The chief results were as follows: In both impact and cross bend tests the blown window glass was stronger than the plate glass. While the energy of impact necessary to produce fracture increased with the thickness of the plate glass, the amount of cracking occurring at the time of initial fracture also increased. The force of the blow required to crack a piece of glass of a given kind and thickness was not materially increased by the celluloid coating, but the shattered glass remained in place while the plain glass was scattered. In the cross bend tests the treated glass of a given kind and thickness was about 15 per cent. weaker than the plain glass when the celluloid-coated side was in compression, and about 40 per cent. stronger when the celluloid-coated side was in tension.

BARIUM GLASSES.—H. Fritz (*Sprech.*, **51**, 51, 1918). Report of trials made in crucibles heated to cone 4a—6a. Most of the mixtures did not melt at all. The general conclusions were that mixtures of baryta and quartz alone do not melt within this range of temperatures, nor with the addition of alumina, nor with the addition of potash (with or without alumina). It was only with the further addition of zinc oxide that bright glasses could be obtained, and then only within certain limits, namely, a minimum of $0{\cdot}6BaO$, and not less than $0{\cdot}1Al_2O_3.2SiO_2$.

ACID POLISHING OF GLASS.—O. Parkert (*Sprech.*, **51**, 162, 1918). A short description of the method employed, including a preliminary cleansing in dilute sulphuric acid (containing also a little hydrochloric acid), then dipping for about 45 seconds in an acid bath for the polishing, followed by washing in water. The polishing bath contains as a rule water, sulphuric acid, and hydrofluoric acid. The method of polishing is said to be suitable for all glass-wares, and also to be fairly cheap and without any particular difficulty in working.

PRACTICAL IMPORTANCE OF CHEMISTRY FOR THE GLASS INDUSTRY.—L. Springer (*Sprech.*, **51**, 173, 175, 181, 187, 1918). A general survey, but with special reference to valuation of the raw materials and substitutes (sodium silicofluoride is mentioned as having been used as a substitute for borax), calculations concerning glass batches and glasses, removal of defects in manufacture, chemistry in side operations (production of refractory products, etc.) and refining, and control of the firing arrangements.

FURNACE CONSTRUCTION IN SMALL GLASS WORKS.—O. Parkert (*Sprech.*, **51**, 217, 1918). An illustrated description of special furnaces used.

INFLUENCE OF ALUMINA ON THE FUSIBILITY OF GLASSES.—L. Springer (*Ker. Rund.*, **26**, 1, 1918). The concluding article of a series contained in the previous volume.

METAL STENCILS FOR GLASS DECORATION.—C. Fleck (*Ker. Rund.*, **26**, 6, 1918). Refers to cheap methods for glass etching or glass painting. Preferably copper or brass is used, tinfoil being too weak, and thin zinc only suitable for coarse objects. The composition of several suitable solutions is given.

A PICTURE TRANSFER PROCESS FOR GLASS-ETCHING.—C. Fleck (*Ker. Rund.*, **26**, 44, 1918). A printing plate is covered with a pasty colour, the design is then transferred to a thin paper, which is provided with a layer soluble in water, and the impression is transferred on to the glass without a press. The preparation of the paper is described.

CHEMISTRY IN THE GLASS INDUSTRY.—L. Springer (*Ker. Rund.*, **26**, 229, 239, 1918). See abstract from *Sprech.*, **51**, 173, 175, 181, 187, 1918.

GLASS MANUFACTURE.—T. J. McCoy, U.S. Pat. 1,246,764, Nov. 13th, 1917. A tank furnace is in connection with a second tank, the contents of which are maintained at a suitable temperature. An automatic counterbalancing arrangement keeps the surface of the glass at a constant level in the second tank and in gathering basins placed about its margin.

APPARATUS FOR MAKING SHEET GLASS.—J. Barnes, U.S. Pat. 1,247,617, Nov. 27th, 1917. Consists of an arrangement of rolls for withdrawing the molten glass from the furnace, partially forming it into a sheet, and passing it through a rubber with adjustable casings forming water-jackets and solid wooden blocks. The rubbing blocks may be caused to act on the glass or not without affecting its position in the rolls. Near the outlet of the furnace is placed a lehr, with conveyor, for receiving the glass sheet, the conveyor and rolls being driven at the same speed.

MAKING SHEET GLASS.—J. W. Colburn, U.S. Pat. 1,248,809, Dec. 4th, 1917. A sheet of glass is drawn from a molten mass vertically through a cooling space, and thence to a heating space where the sheet is bent at right angles over a roller, the temperature of the horizontal part of the sheet being then raised to the softening point, after which the sheet is gradually cooled. One face may be hardened by cooling before bending the sheet.

CHEMICAL GLASSWARE.—P. H. Walker and F. W. Smither (*J. Ind. Eng. Chem.*, **9**, 1,090, 1917). A report of comparative tests of American glassware and Jena and Kavalier glass beakers and flasks. The results showed that American glassware was equal to or better than the others for laboratory purposes.

GLASS TANK AND GLASS-DRAWING APPARATUS.—H. G. Slingluff, U.S. Pats. 1,251,931 and 1,251,932, Jan. 1st, 1918. A tank heated regeneratively at one end supplies glass to open drawing-tanks at the other end. The glass from the heated end of the tank is prevented from flowing directly into the drawing tanks by walls projecting from opposite sides of the tank

in front of the drawing tanks nearest to the heaters. The glass-drawing apparatus is partly immersed in the glass in a tank, and has a refractory block with an elongated drawing opening, and with separate blocks moulded at its ends, provided with grooved drawing ledges lying below the edges of the sheet as it is being drawn; a flow of air or molten glass may thus be directed against the sides of the sheet whilst being drawn.

GLASS-DRAWING FURNACE.—G. L. Catlin and D. Morrison, U.S. Pat. 1,255,983, Feb. 12th, 1918. The top stone of an open-topped glass furnace has an annular flange of angular cross section projecting downwards, with its lower edge extending horizontally. The flange fits against a movable pot-bottom of which the opposite faces comprise a central flat portion with a diameter about equal to that of the flange and having a bevelled margin engaging with the lower edge of the flange. The pot-bottom and flange are kept in contact by springs, and the pot-bottom can be raised and lowered, and also rotated in the lower position.

MUFFLE LEER.—H. M. Thompson, U.S. Pat. 1,257,150, Feb. 19th, 1918. A muffle chamber overlies a leer chamber, the horizontal dividing wall consisting of spaced, parallel metal beams ($\perp$ shape) and tiles supported by adjacent beams. Baffle walls placed on the beams compel the products of combustion to take a serpentine course through the muffle chamber.

GLASS.—E. W. Enequist, U.S. Pat. 1,261,015, April 2nd, 1918. Fused lepidolite (or lithia mica) is added to a glass batch. The whole mixture is melted to give a better glass as regards strength, appearance and temper.

GLASS PLATES OR SHEETS.—H. K. Hitchcock, U.S. Pat. 1,178,448, Feb. 16th, 1915 (re-issued, 14,468, May 7th, 1918). Apparatus for the manufacture includes a receptacle for the molten glass, and a drawing aperture with a continuous wall stretching from the interior of the glass to some distance above the level of the glass surface; the aperture gradually increases in area from the bottom upwards so that the surface from which glass is withdrawn can lose heat by radiation. Means are provided for drawing the glass upwards through the aperture and for regulating the temperature of the surrounding walls.

GLASS FURNACE (ELECTRIC).—J. O. Erskine, U.S. Pat. 1,267,317, May 21st, 1918. Two electrodes are partly immersed in the charge of mixed materials, which are melted by the current, glass being produced continuously. The charge itself forms the resistance for generating heat. The melting and working chambers of the furnace may each have its own set of electrodes.

DRAWING SHEET GLASS.—T. H. Chadwick, U.S. Pat. 1,267,849, May 28th, 1918. By means of a gripping contrivance and elevator a continuous sheet of glass is drawn from the melted glass. The edges of the continuous sheet are cooled by an air-blast, and the glass is cut into separate sheets by a moving oxy-acetylene flame, the detached sheets being conveyed more rapidly than the continuous sheet.

LEHR.—Pittsburgh Plate Glass Co. and W. L. Clause, U.S. Pat. 1,268,217, June 14th, 1918. The bottom wall of the lehr for annealing glass is supported on several vertical walls with passages for air betwen them. Heating gases pass through conduits below the bottom wall to heat the lehr, and below these conduits is a heat-storing device which gradually increases in thickness from the back to the front end of the lehr. Cold air may also be passed through conduits below the heat-storing device.

COLOURED GLASS.—H. T. Bellamy (and Western Electric Co.), U.S. Pat. 1,271,652, July 9th, 1918. The batch is made up of sand, red lead, sodium nitrate, antimony oxide, borax, tin oxide, potash, lime, and gold. The mixture is heated to 1,315° C. (2,400° F.), then cooled, and reheated until it becomes plastic.

GAS AND AIR MIXER FOR GLASS FURNACES.—E. Majot, U.S. Pat. 1,273,171, July 23rd, 1918. A combined mixer and heater, comprises two flues, for hot air above and producer gas below, with outlets in a vertical plane, and a third flue (for hot air) with a horizontal outlet near the lower outlets of the other flues, and also with a shutter for regulating the quantity of air passing through it.

GLASS WORKING.—F. L. O. Wadsworth, etc., U.S. Pat. 1,275,178, Aug. 6th, 1918. Successive small quantities of melted glass are segregated from the main mass, and then transported by means of a hot gas under pressure from below the surface of the melted glass into a receptacle; when the latter is full the surplus is returned to the main mass in such a manner that it cannot reach the segregation point for some time.

GLASS FURNACE.—H. E. De Vaughn, U.S. Pat. 1,274,146, July 30th, 1918. A skew block supporting the cap of the furnace has in its lower side a channel with a recess leading upward from it. Within the recess is a hollow flat supporting contrivance (preferably of metal), which is suspended by bars passing upwards through the block. The suspending bars are surrounded by cooling tubes, and a cooling medium also circulates through the hollow supporting contrivance.

POT FOR PLATE GLASS.—C. H. Kerr, U.S. Pat. 1,278,164, Sept. 10th, 1918. Plastic refractory clay is well mixed with 15 to 50 per cent. of very finely divided silica, mostly consisting of grains less than 0·005 inch and preferably less than 0·0025 inch diameter.

GLASS FURNACE.—C. R. Hook, U.S. Pat. 1,279,697, Sept. 24th, 1918. The hot-air flues from the regenerators placed on opposite sides of a glass furnace are connected with an air passage. The outwardly flared end of this passage communicates with the chimney. By means of a damper of the "butterfly" type, either of the two hot-air flues may be put in communication with the chimney and the other one with the air passage.

GLASS MANUFACTURE.—R. H. Bolin, U.S. Pat. 1,280,139, Oct. 1st, 1918. Relates to a stationary tank furnace from which the glass flows into a movable receptacle enclosed by an air chamber through which the glass is conveyed in a continuous sheet by two revolving bodies (one on each side of the chamber) which press on the edges of the sheet. The sheet is supported on a column of compressed air moving in the same direction as the glass. By changing the level of the glass in the receptacle the tension on the glass may be varied.

EFFECTS OF HEAT ON CHEMICAL GLASSWARE.—R. G. Sherwood (*J. Amer. Chem. Soc.*, **49**, 1,645, 1918). When glass is heated there is evidence of two distinct kinds of gaseous evolution, that resulting from adsorbed products which are readily removable at temperatures below 300° C., and that resulting (in all probability) from a chemical decomposition of the glass itself. The latter effect becomes important above 400° for the softer glasses and above 500° for the harder glass. There is some evidence of a definite characteristic rate of gaseous evolution for each temperature to which the glass is subjected, increasing with the temperature and extending over a considerable period; observations on one sample at 500° showed a small continuous evolution even after 20 hours of heating. Adsorption products are confined to quantities which are represented approximately by a layer of gas about one molecule deep and are removed with much greater rapidity at lower temperatures than the other products obtained due to the heating of the glass. The most important of the gaseous evolution products obtained from glass under the influence of heat is water, which, as the temperature is raised to the softening point of the glass, constitutes almost the entire quantity of the evolution, but which at a lower temperature may be relatively unimportant. [The foregoing is the author's summary.]

GAS-COKE-PRODUCER-FIRED TANK FURNACE.—A. B. Roxburgh (*Gas J.*, **141**, 586, 1918). Report of paper read before the Glass Makers' Society at Newcastle-on-Tyne, relating to a tank furnace for production of white glass.

XI.—CEMENTS, MORTARS, CONCRETE, Etc.

MODERN METHODS OF LIME BURNING.—(*Brick Pot. Tr. J.*, **25**, 175, 1917). Relates mainly to continuous kilns of two types, gas-fired shaft kilns and rotary kilns.

THE SINTERING OF PORTLAND CEMENT.—(*Brick Pot. Tr. J.*, **25**, 269, 1917). A general discussion, with some suggestions as to research.

SOME SLOW VOLUME CHANGES IN PORTLAND CEMENT.—E. D. Campbell (*Cement Eng. News*, **29**, 144, 1917). From the *Journal of Industrial and Engineering Chemistry*, **8**, 1,101, 1916. See also Trans., **16**, Abs. 122, 1917.

LIMES AND CEMENTS.—O. Boudouard (*Chr.*, **20**, 170, 1917). A general survey of the industry, including a discussion of recent work done in America and elsewhere. Also special references to the composition, etc., of white cement and grey cement, and of tests for cement.

RECENT RESEARCH ON CEMENTS.—K. Endell (*Zeits. angew. Chemie*, **31**, 233, 238, 1918). A review of cement researches of the last ten years, with a bibliography for that period.

MANUFACTURE OF PORTLAND CEMENT.—E. D. Boyer (*J. Soc. Chem. Ind.*, **37**, 19T, 1918). A brief account of Portland cement, including the Cottrell electrical precipitation method of removing suspended particles from the gases, and the recovery of potassium compounds, and also the grinding of the cement.

NATURAL HYDRAULIC CEMENTS IN NEW YORK.—R. W. Jones (*J. Amer. Cer. Soc.*, **1**, 160, 1918). An illustrated general account of the geology, mining, and burning of the cements.

TIME OF SET OF CALCINED GYPSUM.—F. F. Householder (*J. Amer. Cer. Soc.*, **1**, 578, 1918). The relation of the time of set to the other physical properties depends on the purity of the raw gypsum, the temperature at which it is calcined, and the amount of accelerator or retarder added; experience shows that it also depends on the cleanliness of the boxes in which the plaster is mixed, and the purity of the water used. The present preliminary report deals with tests made to determine the effect of varying the consistency of the mixtures, the time and rate of stirring, and the temperature of the mixing water, the same grade of plaster being used throughout.

The author concluded that increase in the proportion of water causes a decrease in viscosity and an increase in the time of set of calcined gypsum, that vigorous and continuous agitation (during the mixing) tends to decrease the time of set, and that the temperature of the water has no effect on the time of set.

HYDRAULIC PROPERTIES OF THE CALCIUM ALUMINATES.—P. H. Bates (*J. Amer. Cer. Soc.*, **1**, 679, 1918). All the calcium aluminates —$3CaO.Al_2O_3$, $5CaO.3Al_2O_3$, $CaO.Al_2O_3$, and $3CaO.5Al_2O_3$—except the tricalcium aluminate, have hydraulic properties; but only two of the four calcium silicates, namely, $2CaO.SiO_2$ (β-form), and $3CaO.SiO_2$. The tricalcium aluminate, curiously enough, is the only aluminate present in normal Portland cement. The other calcium aluminates acquire at early periods greater strength than Portland cement acquires in the same time.

Each of the four aluminates is considered in turn. Several illustrations and tables are given, including results of tests, etc. The conclusion is that it

is possible to make, by a method and equipment similar to that for Portland cement, cements giving in 24 hours strength as high as those usually developed by Portland cement in 28 days—either as a mortar or concrete. This quick-hardening cement is not quick-setting. It is a calcium aluminate high in alumina (preferably 55 to 75 per cent.). The presence of silica or iron oxide is not desirable but may be present in amounts up to 15 per cent.—provided they replace the lime and not the alumina.

The actual cost of manufacture would not exceed that of Portland cement, but unfortunately the cost of the alumina would be prohibitive except for very special purposes.

CALCAREOUS CEMENTITIOUS MATERIAL.—W. E. Carson, U.S. Pat. 1,248,455, Dec. 4th, 1917. Commercial fine ground cement has its plasticity increased by the addition of similar cement ground much more finely.

CEMENT CLINKER.—T. Hattori (*J. Chem. Ind.*, Tokyo, **20**, 701, 1917). Relates chiefly to microscopical examination. Surfaces of cement clinker etched with water, or with dilute HCl or HF, show two main constituents, alite and celite; alite consists of crystals with square or hexagonal section, and celite is the intervening ground mass, consisting of a white and grey substance, with also eutectic structures (especially in clinker from stationary kilns). Alite is more readily attacked than celite by water and dilute HCl, but less readily by HF. Some clinkers after being etched with dilute HF reveal unattacked clusters of white granules, which behave like alite when water or dilute HCl is used for etching. Hence HF is preferable as an etching reagent. The finer alite grains in cement from a stationary kiln is due to the difference in cooling. Alite grains in well-burned clinker have sharp outlines, which are rounded and indefinite in incompletely burned clinker. The alite increases with the proportion of lime. In good clinker the alite is regularly distributed, so that chemical analysis alone does not clearly indicate the quality. See also abstract in *J. Soc. Chem. Ind.*, **37**, 59A, 1918.

PORTLAND CEMENT BRIQUETTES.—T. Hattori (*J. Chem. Ind.*, Tokyo, **20**, 1,018, 1917). As there is no simple relation between the strength of a cement and that of mortar made from it, the suggestion is advanced that tests should be applied to a mixture of cement and sand rather than to neat cement. The value of a cement depends on the proportion of "flour," since the coarser particles (or grit) is not hydrated on being mixed with water. Increase in the proportion of "flour" decreases the tensile strength of neat cement briquettes, but increases that of mortar briquettes, and *vice versa* when the grit is increased. Hardened cement under the microscope shows a mass of non-hydrated grains embedded in the hydrated material. The hardness of neat cement after setting is proportional to the percentage of grit in the section—hence the low tensile strength of neat briquettes made from fine cement, and the density and high strength of mortar in which the fine cement is able to carry so much sand. See also abstract in *J. Soc. Chem. Ind.*, **37**, 59A, 1918.

BOILING TEST FOR PORTLAND CEMENT.—T. Hattori and K. Fujisawa (*J. Chem. Ind.*, Tokyo, **20**, 1,205, 1917). In Le Chatelier's boiling test for cement, the expansion due to dipping in water immediately after moulding should be noted, as it may exceed the expansion due to boiling. The authors do not consider it necessary to boil for the specified six hours. See abstract in *J. Soc. Chem. Ind.*, **37**, 209, 1918.

GRIT IN PORTLAND CEMENT.—T. Hattori (*J. Chem. Ind.*, Tokyo, **20**, 1,212, 1917). The grit which passes through a sieve with 900 meshes per sq. cm., but not through a 2,500 mesh, may cause the cement to expand in the boiling test. By removing the grit the soundness of the cement is improved. See abstract in *J. Soc. Chem. Ind.*, **37**, 209, 1918.

CEMENT AND POTASSIUM COMPOUNDS.—C. Ellis, U.S. Pat. 1,250,291, Dec. 18th, 1917. Finely divided silicate rock is sprayed with solution of

alkaline earth chloride (enough to convert all the potassium into chloride), and the mixture is passed along a heated inclined cylindrical chamber. Most of the potassium is volatilized and recovered as chloride. The non-volatile portion is mixed with suitable calcareous material, and the mixture heated to produce cement clinker.

PLASTER OR CEMENT COMPOSITIONS.—H. S. Thatcher, U.S. Pats. 1,251,841, and 1,251,842, Jan. 1st, 1918. Calcined gypsum and porous, non-crystalline silica (as uncalcined kieselguhr) are ground together to form an intimate mixture, or are simply mixed dry in a finely divided state.

MORTAR FOR FIREBRICKS.—A. B. Cox, U.S. Pat. 1,252,785, Jan. 8th, 1918. A mortar for firebricks, vitrifiable at a comparatively low temperature, consists of 75 parts shale, 25 ground firebrick, 30 sodium silicate, and 75 asbestos,

EFFECT OF CALCIUM SULPHATE ON CEMENT.—J. C. Witt and F. D. Keyes (*Philippine J. Sci.*, **12**A, 133, 1917). Calcium sulphate, added to cement to the extent of 1·5 to 2·0 per cent. SO_3, retards the setting time without decreasing the tensile strength, but further additions accelerate the time of setting and also decrease the tensile strength. The soundness of the cement, as tested by five hours in steam, was unaffected by the addition of calcium sulphate up to 10 per cent. SO_3. See abstract in *J. Soc. Chem. Ind.*, **37**, 150A, 1918.

GREAT WALL OF CHINA.—J. C. Witt (*Philippine J. Sci.*, **12**A, 257, 1918). Samples of brick and mortar had the following composition :—

	Loss on Ignition	SiO_2	$Al_2O_3+Fe_2O_3$	CaO	MgO	Na_2O+K_2O
Brick ...	0·10	73·02	18·96	1·29	1·05	5·73
Mortar ...	43·88	2·12	0·44	48·83	4·03	0·85

The bricks had apparently been only sun-dried, as the material turned red on ignition. No sand had been mixed with the mortar.

CEMENT AND CONCRETE.—J. C. Witt (*Philippine J. Sci.*, **13**A, 29, 1918). Relates to the influence of certain chlorides, nitrates, sulphates, and bicarbonates on the setting of cement. The tensile strength was generally lowered. The time of setting was retarded, the retardation in some cases increasing with the concentration, in others at first increasing and afterwards decreasing as concentration increased. See abstract in *J. Soc. Chem. Ind.*, **37**, 336A, 1918.

SWELLING OF SILICA AND PORTLAND CEMENT.—V. Rodt (*Chem. Ztg.*, **42**, 173, 1918). Finely ground cement or certain forms of silica swell up and form loose, flocculent material, on treatment with lime-water or solutions like alum, ammonium carbonate, etc. Quartzite and other forms of free silica swell less than silica set free from certain silicates. The swelling seems to be caused by absorption of water in some way incompletely understood.

CEMENT.—E. C. Eckel, U.S. Pat. 1,255,995, Feb. 12th, 1918. A suitable quantity of diatomaceous earth is added to a cement mixture containing iron and calcareous material. The clinker should contain more than twice as much combined silica as sesquioxides.

CEMENT.—W. H. Allen, U.S. Pat. 1,261,750, April 9th, 1918. A cement paste is made from powdered magnetite and solution of an acid compound of phosphorus (as a 50 per cent. solution of phosphoric acid).

HYDRAULIC CEMENT.—F. M. Meyer, Ger. Pat. 303,177, Dec. 20th, 1912. Relates to a cement consisting of 30 parts dust from gas-filters (used in the dry gas cleaning process) and 70 parts slaked lime. This cement, mixed with 3 parts normal sand, has a crushing strength of 209 kilog. per sq. cm. after 8 days, and 224 kilogs. per sq. cm. after 28 days.

BURNING SLOW-SETTING PLASTER.—Petry and Hecking, Ger. Pat. 301,932, March 17th, 1915. The gypsum is crushed into nearly uniform particles, and is first burned in a strongly heated drum until dehydration begins, and then in a less strongly heated drum (which may be heated by the waste gases from the first).

HOLLOW BLOCKS FROM CEMENT AND ARTIFICIAL STONE.—S. Röhm, Ger. Pat. 302,137, Dec. 28th, 1916. The concrete or artificial stone is placed about a core of ice and left to harden, vents being provided in the concrete or stone for the escape of the liquified ice.

HYDRAULIC LIME FROM PURE LIME.—G. Pralle, Ger. Pat. 302,139, Feb. 16th, 1916 Air-slaked lime—hydrated and carbonated—is mixed with freshly burned and freshly slaked lime, and the mixture stored in a silo. Mortar made from the product sets as quickly and as hard as mortar prepared from natural hydraulic lime.

ALKALI AND CEMENT FROM MINERALS.—F. Krupp, Ger. Pat. 304,080, April 9th, 1914. The alkali-containing mineral is heated with calcium carbonate and the calcium salt of another acid (as calcium sulphate), and in some cases with a corrective agent (as silica), so as to get at the same time a cement and the total alkali; if necessary, ferric oxide must be introduced to make up about a quarter of the total weight of alumina and ferric oxide. If these points are properly attended to the decomposition is practically quantitative below clinkering temperature.

PLASTER COMPOSITION.—P. S. Anneke, U.S. Pat. 1,264,747, April 30th, 1918. Hydrated lime and amorphous silica (kieselguhr) are ground together.

PLASTER COMPOSITION.—H. Blumenberg, jun., U.S. Pat. 1,266,200, May 14th, 1918. Consists of equal parts of deadburned gypsum, and the hemihydrate of calcium sulphate (plaster).

CEMENT CLINKER.—T. Hattori (*J. Chem. Ind.*, Tokyo, **21**, 306, 1918). Relates to microscopical examination, and forms Part II (for Part I see abstract from same *J.*, **20**, 701, 1917). In well-burned clinker the alite grains from a Dietzsch kiln are intermediate in size between those from a stationary kiln and a rotary kiln; in under-burned clinker (from Dietzsch kiln) the alite grains were small and round, instead of large and square or hexagonal. Celite, etched with alcoholic dilute HCl, shows by reflected light sharply divided white and grey areas bounded by straight lines. The white parts resist the etching reagent, while the grey is easily attacked. It is misleading to judge the quality of Portland cement by its hydraulic modulus, unless the effect of free lime present be taken into account. For somewhat longer abstract see *J. Soc. Chem. Ind.*, **37**, 468A, 1918.

PORTLAND CEMENT.—T. Hattori (*J. Chem. Ind.*, Tokyo, **21**, 297, 1918). Relates to absorption of carbon dioxide by cement on aeration. The CO_2 was found to have increased after 22 weeks exposure from 0·40 to 4·57, and from 0·48 to 4·88. Some water was also taken up. The graph showing rate of absorption of CO_2 was a straight line.

ELASTICITY OF NEAT CEMENT.—L. Jouane (*Comptes rend.*, **167**, 591, 1918). See abstract in *J. Soc. Chem. Ind.*, **37**, 700A, 1918.

DESTRUCTIVE ACTION OF CALCIUM ALUMINIUM SULPHATE.—Nitzsche (*Zeits. angew Chem.*, **31**, 195, 1918). This compound is formed by bringing together lime water, precipitated alumina, and a sulphate in solution, but free lime is necessary for its stability. As most natural waters contain sulphate they affect cement, but sea water apparently does not cause the double sulphate to be formed. Cement or concrete can be protected by coating it with bituminous material, or by such a modification of the constitution of the cement as will avoid the formation of the double sulphate.

ARTIFICIAL STONES, etc.—H. Petersen, Ger Pat. 306,952, Aug. 5th, 1917. Relates to such stones, etc., as contain cement. The cement is mixed with finely ground air-dried marl.

BURNING GYPSUM.—E. Fischer, Ger. Pat. 307,808, Jan. 1st, 1918. Uniform quality of plaster of Paris is produced from gypsum of varying density by burning the gypsum in pieces of size inversely proportional to density.

XII.—ANALYTICAL PROCESSES.

METHODS OF GLASS ANALYSIS.—E. T. Allen and E. G. Zies (*J. Amer. Cer. Soc.*, **1**, 739, 1918). Refers more particularly to accurate methods for determining the two oxides of arsenic and boric acid. Other features are the determination of iron in optical glasses, of zinc, and of lead and barium occurring together; also separation of alumina from barium and calcium, analysis of glasses containing boric acid, determination of moisture, gases in glass.

A table gives nine analyses of Jena optical glasses and one American optical glass.

XIII.—INSTITUTES, EDUCATIONAL, HISTORICAL.

OLD THURINGIAN PORCELAIN.—(*Tonwar. Ofen. Ztg.*, **41**, 144, 1917). A brief notice of the collection in the Thuringian Museum at Eisenach, which includes specimens from the old factories at Volkstedt, Kloster Veilsdorf, Gotha, Wallendorf, Gera, Limbach, Ilmenau, Groszbreitenbach, Rauenstein, Schney, Tettau, and Eisenberg.

HOW GLASSES ARE FORMED.—C. Loeser (*Glash.*, **47**, 1, 17, 33, 49, 66, 98, 113, 129, 145, 1917). A general historical account of the development of the glass industry, with brief notices of changes in methods and materials, both for ordinary types and for special varieties.

DEVELOPMENT OF THE BAVARIAN GLASS INDUSTRY.—L. Springer (*Glash.*, **47**, 276, 289, 305, 322, 337, 369, 1917). A historical account from the origin in the tenth century to the present time.

ESTABLISHMENT OF THE GERMAN OPTICAL INDUSTRY.—(*Glas.-Ind.*, **28**, No. 5/6, p. 1, 1917). It was founded at Rathenow in 1800 by J. H. A. Duncker, who was born in 1767 and died in 1843. The works have been carried on by successors.

THE TERM "CERAMIC."—J. W. Mellor (*Pot. Gaz.*, **42**, 155, 1917). A discussion of the origin and meaning of the term. See also TRANS., **16**, 69, 1917.

AMERICAN CERAMIC ENGINEERING.—(*Pot. Gaz.*, **42**, 172, 1917). A description of the Ceramic Engineering Building of the University of Illinois, with an account of the dedication.

NECESSITY FOR SCIENCE AND ART IN THE PRODUCTION OF MODERN POTTERY.—John Eyre (*Pot. Gaz.*, **42**, 383, 1917). See TRANS., **16**, 158, 1917.

DANISH FAIENCE.—(*Pot. Gaz.*, **42**, 501, 1917). A brief illustrated description of the manufactory founded in 1863 and its artistic productions.

COPENHAGEN PORCELAIN.—(*Pot. Gaz.*, **42**, 581, 1917). A short illustrated article supplementary to the foregoing.

SICILIAN POTTERY.—(*Pot. Gaz.*, 42, 791, 1917). A brief review of the collection of pottery, etc., in the new Sicilian Museum established by the late Professor G. Pitre.

ROMAN POTTERIES AND KILNS AT HOLT (DENBIGHSHIRE).—T. A. Acton (*Pot. Gaz.*, 42, 1,067, 1917). A description of the author's discoveries during recent excavations at a site adjoining Watling Street, including the best preserved tile and pottery kilns hitherto discovered in the Roman provinces. More ancient pottery was briefly reviewed, and then Arretine ware and other Roman pottery were considered. The foundations of the kilns and buildings were very solid. The fire hole and combustion chamber, with the flues, seem always to have been below the original ground level. The floor of the kiln was generally 2 to 3 feet below this ground level, the part of the upper chamber or oven above the ground being (as usual) absent. The excellent state of preservation of the fire holes, flues, and lower chambers is owing to underground drainage of slightly higher ground on the west.

The barracks for the pottery people was in a large rectangular enclosure, 62 yards by 125 yards. There was also a small villa, with a bath-house, and in the drain from the bath were found a gold chain, gems from signet rings, and many fibulæ. Foundations of manufacturing buildings were also unearthed, and on the baked tiles were footprints of naked feet, nailed boots, and of dogs and other animals.

Practically every description of Romano-British pottery was made at Holt, but the chief was a reddish body coated with a fine slip.

LOWER LUSATIAN POTTERIES IN FORMER TIMES.—K. Strausz (*Deut. Töpf.-Zieg.-Ztg.*, 48, 164, 1917). A brief account of blue-painted and other cylindrical stoneware pots of white-brown or whitish grey colour, similar to Westerwald and Nassau products, from Lower Lusatia (Niederlausitz) in East Germany. The now unimportant town of Triebel was once famous for excellent stoneware. A few pieces are illustrated.

EAST GERMAN EARTHENWARE MANUFACTURE.—K. Strausz (*Deut. Töpf.-Zieg.-Ztg.*, 48, 212, 1917). Short accounts of the eighteenth century Royal Saxon Earthenware Factory at Hubertusburg, Silesian and Brandenburgian Earthenware Factories of the nineteenth century, and the eighteenth century Guischard Earthenware Factory in Magdeburg.

BUNZLAU—FORMERLY A CERAMIC ART CENTRE.—K. Strausz (*Deut. Töpf.-Zieg.-Ztg.*, 48, 331, 1917). A historical account of the ceramic activities. Documentary evidence shows that the oldest potter died in 1522, and the guild was established in the sixteenth century. A list of publications is given, and a list of collections (all German) in which Bunzlau products are included. Some of the products are described, mostly brown stoneware, with decoration, a few being illustrated.

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